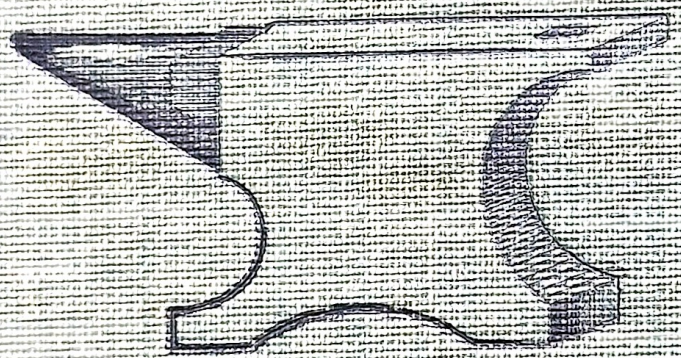
MANUAL OF BLACKSMITHING



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MANUAL OF BLACKSMITHING

CHAPTER I.

FORGES AND APPLIANCES.

It is but fitting that the first chapter of a handbook on the art of the blacksmith should contain descriptions of the various appliances necessary to the performance of the work. The principal of these are noticed in this chapter, descriptions of the hand tools being given in the next chapter; descriptions of those appliances that require to be specially made for individual jobs are included in the explanations of the processes further on. Brief notices of some of the principal forges will be useful as a guide to the choice of one. Portable bellows forges, both rectangular and circular, are made in a great many sizes. One with a hearth measuring about 25 in. by 18 in. is sufficiently large for a single-handed worker, and in it bar iron up to 1 in. or 1¼ in. square may be heated. For heavier work, requiring the aid of a hammer-man, the hearth may measure 33 in. by 26 in., and range thence up to 39 in. by 30 in. for the largest work. The common forge built of bricks or stone is suitable for average and occasional heavy work.

Fig. 1 illustrates a medium size forge with half hood; it is adapted for machinists, plumbers, miners, marble workers, millers, repair shops, farmers and locksmiths.

Fig. 2 illustrates the noted Standard Lever Black-

smith Forge. The lever motion used on this forge has been in use for fifteen years, and is now on over 225,000 forges and blowers throughout the world.

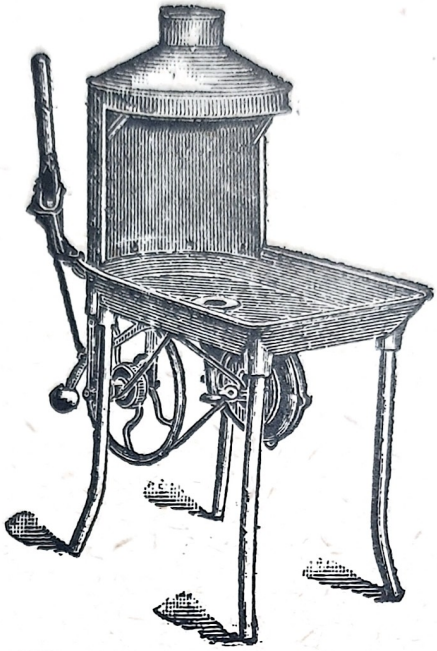

Fig. 1.—Illustrates a Medium-Size Forge.

The Joint Brass Oscillating Journal Bearings which is a feature of this forge prevent all twisting and binding of the bearings. The oil chambers, when filled, hold oil for lubricating the bearings automat-

Fig. 2.—Illustrates Standard Lever Blacksmith Forge.

ically six months, or 153 working days, without further attention. The brass bearings are adjustable over the entire length of the bearings, with

hardened steel lock nut end-screws, for taking up all wear on the fan. Another special feature is the slope bottom coal box, which is beneath the level of the bottom, thus being entirely out of the way. Wet or damp coal is often very necessary when heavy work is being done, and no forge is complete without a sloped coal box.

A lever blacksmith blower is illustrated by Fig. 3. In this forge the lever motion is perfect in its construction, and cannot get out of order; it is light

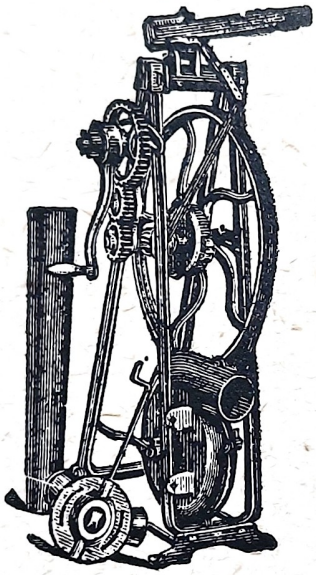

Fig. 3.—A Lever Blacksmith Blower.

running, with a continuation of momentum between strokes, keeping the blast regular and powerful. It has a 16-in. fan and 25-in. fly-wheel, with a capacity of a 50-in. bellows.

Fig. 4 illustrates a horseshoer's forge. This has been designed and substantially constructed for horseshoers, blacksmith's fires. It is easy running and noiseless, and, when thoroughly known, will be appreciated by every blacksmith who makes a specialty of shoeing horses. The blast is powerful enough for all kinds of light and heavy blacksmith's work, including the heaviest railroad work.

A smith's bellows is illustrated by Fig. 5, and this can be obtained in sizes varying from 24 in. to 40 in. long.

A fan blower is especially adapted for blowing

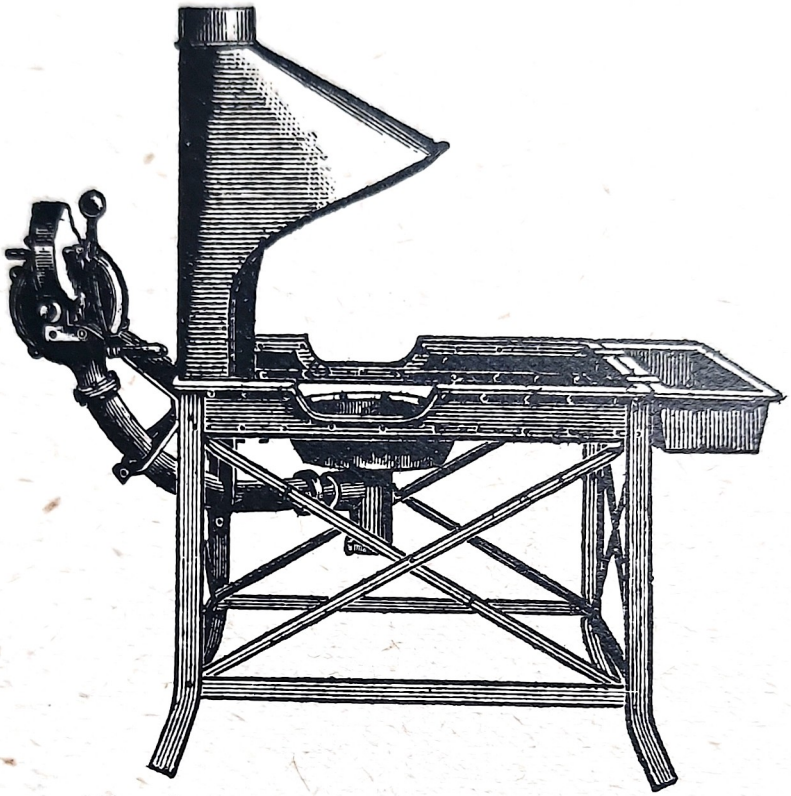

Fig. 4.—Illustrates a Horseshoer's Forge.

forge fires, boiler fires, steam boiler furnaces, puddling and heating furnaces, dry rooms, refrigerators, or for ventilation, and is illustrated by Fig. 6.

Fig. 5.—Illustrates a Smith's Bellows.

A blower is undoubtedly the best; its equal and continuous blast is superior to the spasmodic, variable, and intermittent current from bellows. There are several kinds of blowers used in portable forges,

but there is not very much to choose between them. In workshops a row of forges will be supplied with blast from a single fan or blower, each forge being furnished with a throttle valve in its tuyere pipe.

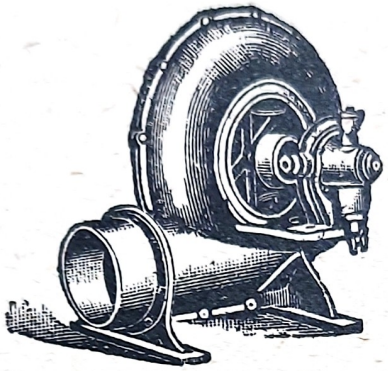

Fig. 6.—Illustrates a Fan Blower.

The old-fashioned bellows are still found in country shops; but in the modern establishments a fan blast or a blower is used, either being superior in all respects to the bellows.

In small forges, the tuyere is a simple tube. The thickening-up of the nozzle serves to preserve it from destruction for a very long period, and the casting, when burnt away, is replaced. But in all large forges operated by powerful blast, the tuyere

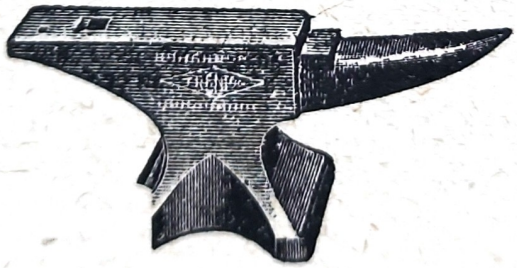

Fig. 7.—The American Wrought Anvil.

is surrounded with water, which protects the nose from the destructive heat of the fire.

The American wrought anvil (Fig. 7) ranges in weight from about sixty pounds up, and is made of

steel-faced wrought iron. A double-piked anvil is shown by Fig. 8 and a farrier's anvil by Fig. 9. The conical end (A) or "beak" is used for turning bars upon, and the hole (B) is for the reception of the anvil chisel, and various bottom tools. Care should

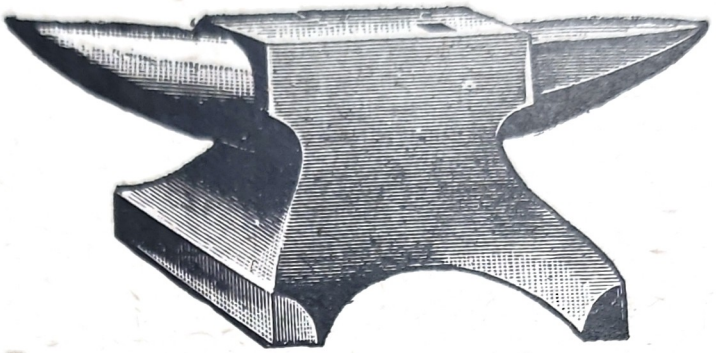

Fig. 8.—Double Piked Anvil.

be taken that the edges of the anvil are not bruised.

The anvil is supported so that its face is about 22 in. high from the ground by a stand which is often a block of wood. The anvil is prevented from slipping sideways by spikes driven into the wood close alongside the anvil-feet. An iron stand (Fig. 10) is much firmer than one of wood, though its first cost is greater.

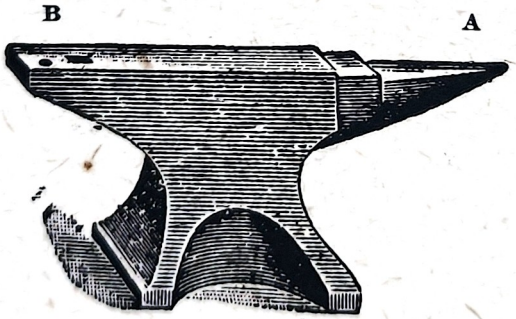

Fig. 9.—Farrier's Anvil.

The anvil wears hollow on the surface in the course of time, and its edges become rounded; the less this occurs the better, as an anvil needs to be true when flatting over large surfaces and square corners. Occasionally, but very seldom, the beak is

broken off, either as the result of faulty construction or very rough usage.

The ordinary tail or standing vice is, on the whole, as good as any. Vices with parallel jaws and instantaneous grip arrangements used by fitters are scarcely suitable for the smithy, where the work is mostly of a rough character. The tail-vice may be attached to a regular bench put up in the smithy, or a small bench only two or three feet in length may be attached to the wall near the forge, and the vice fastened to that; or it may be self-contained, standing on a tripod framework of wrought iron, and so be movable about the shop.

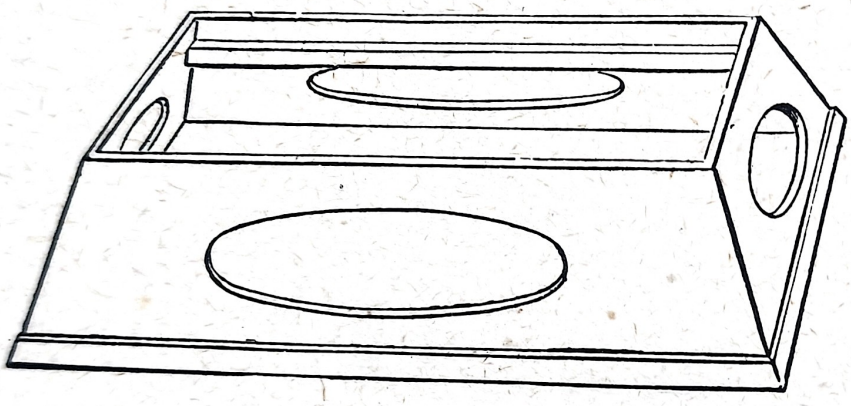

Fig. 10.—Anvil Stand.

In a shop not provided with steam power, the Oliver hammer is a useful tool, and may easily and cheaply be rigged up by smith and carpenter; though not so rapid in its action as a steam-hammer, it is the best substitute for one. If power is available, the drop-hammer is an improvement on the Oliver, and is employed in many large firms. The steam-hammer is, however, the most efficient, but it consumes a large quantity of steam, requires the attendance of a man to operate the valves, is costly, and therefore only suitable to large shops.

Figs. 11 and 12 show a front and a side view of an Oliver hammer, as often fitted up in country shops, where the appliance is often entirely home-

made. A, A, are stout wooden posts driven deeply into the ground, between them being pivoted on dead centers a piece of wood, B, of either round or square section. Iron centers are driven into the end of B, and these are pivoted upon studbolts, C, C. The pivots and the countersunk holes should be case-hardened, and iron bands, D, D, should be shrunk on to prevent the wood, B, being split out at the ends. The hammer-shaft, E, is mortised into B, over

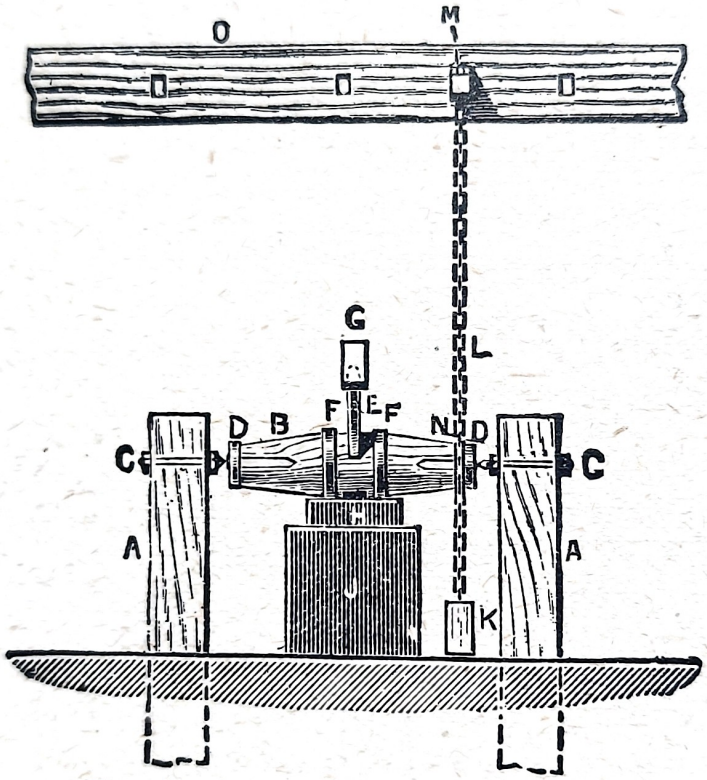

Fig. 11.—Front of Oliver Hammer.

which, on each side of the hammer-shaft, bands, F, F, are shrunk, to prevent the concussion of the hammer blows splitting the wood. The hammer-head, G, is recessed as shown, to receive top swages, and corresponding bottom swages are let into the anvil, H, which, in turn, rests upon a massive anvil-block, J.

The Oliver hammer is worked by the smith with his foot upon the treadle-board, K, to which one end of a chain, L, is attached, the other end being fast-

ened to a flexible wooden pole, M. A short lever, N, is fastened to the chain between K and M, and this lever being driven into B, of which it forms a part, moves B on its pivots and causes E and G to descend with the treadle, K. On the release of the foot, G is pulled up by the spring bar, M, which is tenoned into a stout beam, O, which is fastened to the wall. There are several forms of drop hammers, a com-

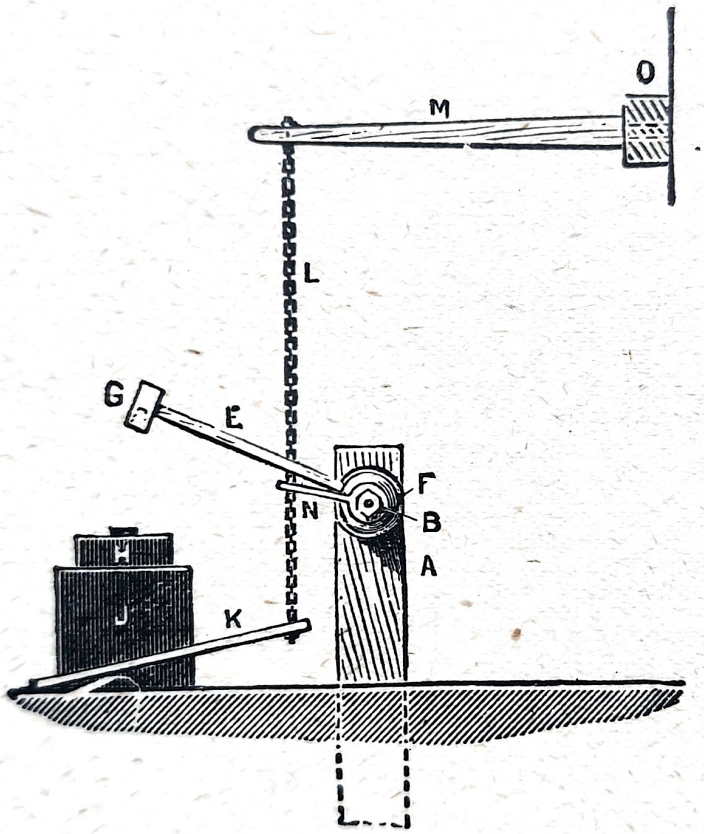

Fig. 12.—Side of Oliver Hammer.

mon arrangement being to attach the hammer to the lower end of a belt which is fastened to a pulley, the latter being revolved as required by friction cones, operated with a disengaging clutch. When the latter is released the hammer falls; on again throwing it into gear, the hammer is lifted. The clutch is controlled by means of a lever handle, within easy reach of the attendant.

A monkey or swinging pendulum hammer is illustrated by Fig. 13. It is made of cast iron, and is balanced carefully on its center of gravity by the correct setting in position of the eye, B, which is cast into the bar. The battering end is preserved from fracture, and from too rapid wear, by means of the wrought-iron band, C, which fits around, and is shrunk into a shouldered recess of dovetailed section. The handle, or porter, D, is of wrought iron cast into the monkey. It is provided with an eye, through which a small chain or rope, E, is passed; by means of this the monkey is pulled backwards after every blow. The monkey is suspended by a chain, A, from any convenient beam overhead. It is

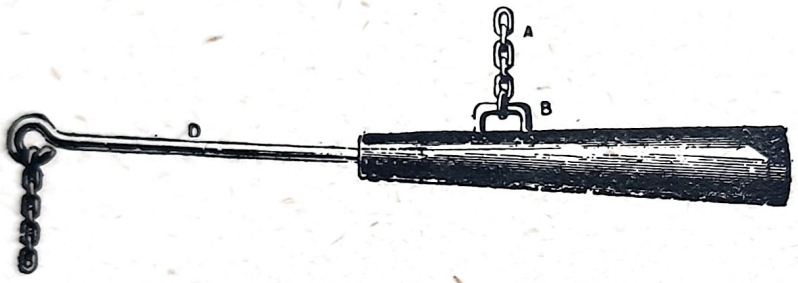

Fig. 13.—Swinging Monkey.

drawn back several feet from the perpendicular, and then let go; being heavy, it strikes the iron with great force.

The smith's mandrel, Fig. 14, a conical hollow casting, is employed chiefly in making rings, as will be explained, and should be kept in three or four sizes.

An appliance employed for rounding off the heads of bolts is shown in plan and elevation by Figs. 15 and 16. A is a bracket-like casting, bolted firmly to a heavy cast-iron base let into the ground. Through an overhanging boss at the top of A slides the shank of the rounding tool, B. This is plumb over a bolster, C, on the base. The bolt is dropped into the bolster, C,

and the tool, B, struck upon it with a sledge hammer. The support, D, is merely for the purpose of supporting the rounding tool while the bolt is being slipped

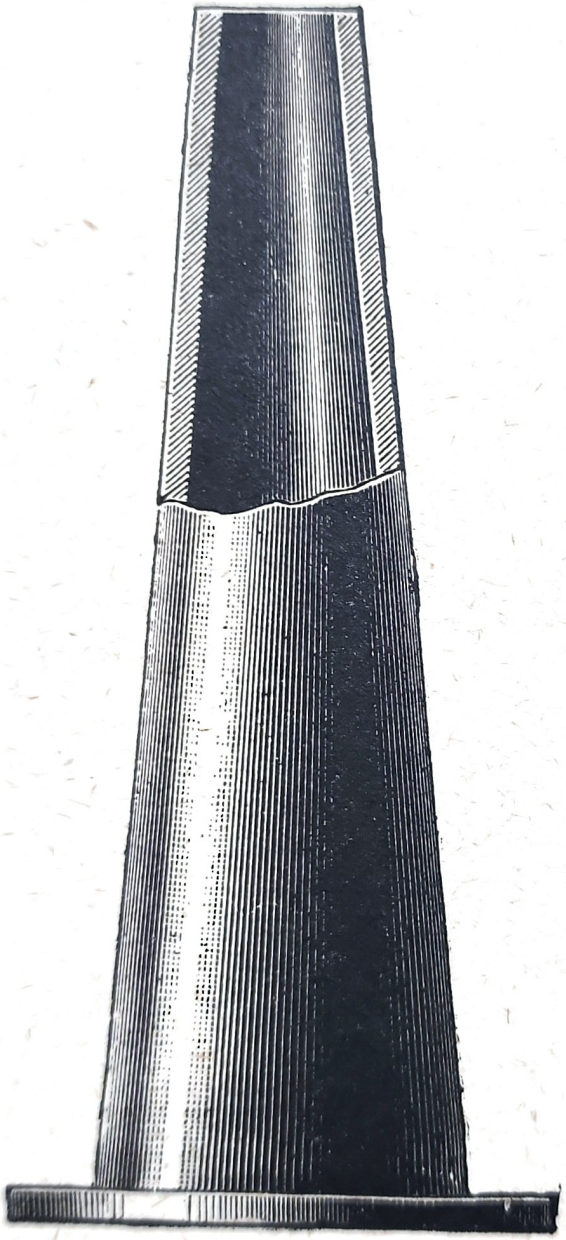

Fig. 14.—Sugar-loaf Casting.

into the bolster. It is pivoted to a strap fastened to the side of A, and is turned to one side when the tool is being struck with the hammer.

A bolt-forging machine is power-driven, and by its means bolts and their heads are formed between dies having a rapid vertical movement imparted from a long cam shaft. Where bolts are made in even moderate quantities, the bolt-machine soon pays for itself. An almost necessary adjunct to this machine is the power-driven hot and cold iron saws. The first is a comparatively thin saw, run dry at a high rate of speed, that cuts roughly through red-hot

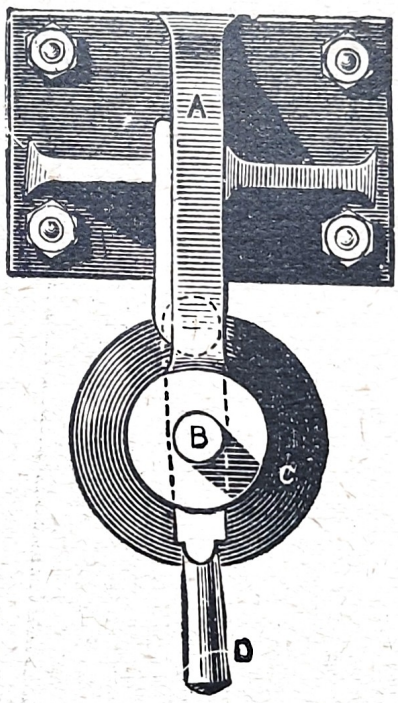

Fig. 15.—Plan of Appliance for Rounding Bolt Heads.

rods and bars almost instantly. The second is a thicker saw, that cuts slowly, but smoothly and cleanly, running in water the while.

Two forms of carriers are commonly employed to move and carry about bars which are too long to be manipulated by the tongs. One (Fig. 17) is used underhand, being carried vertically with the hook lowermost, and the work, or one end of it, slung

in the hook. The other (Fig. 18) is used for heavy forgings, being carried by two men. When one end of the work is carried thus, the other may be

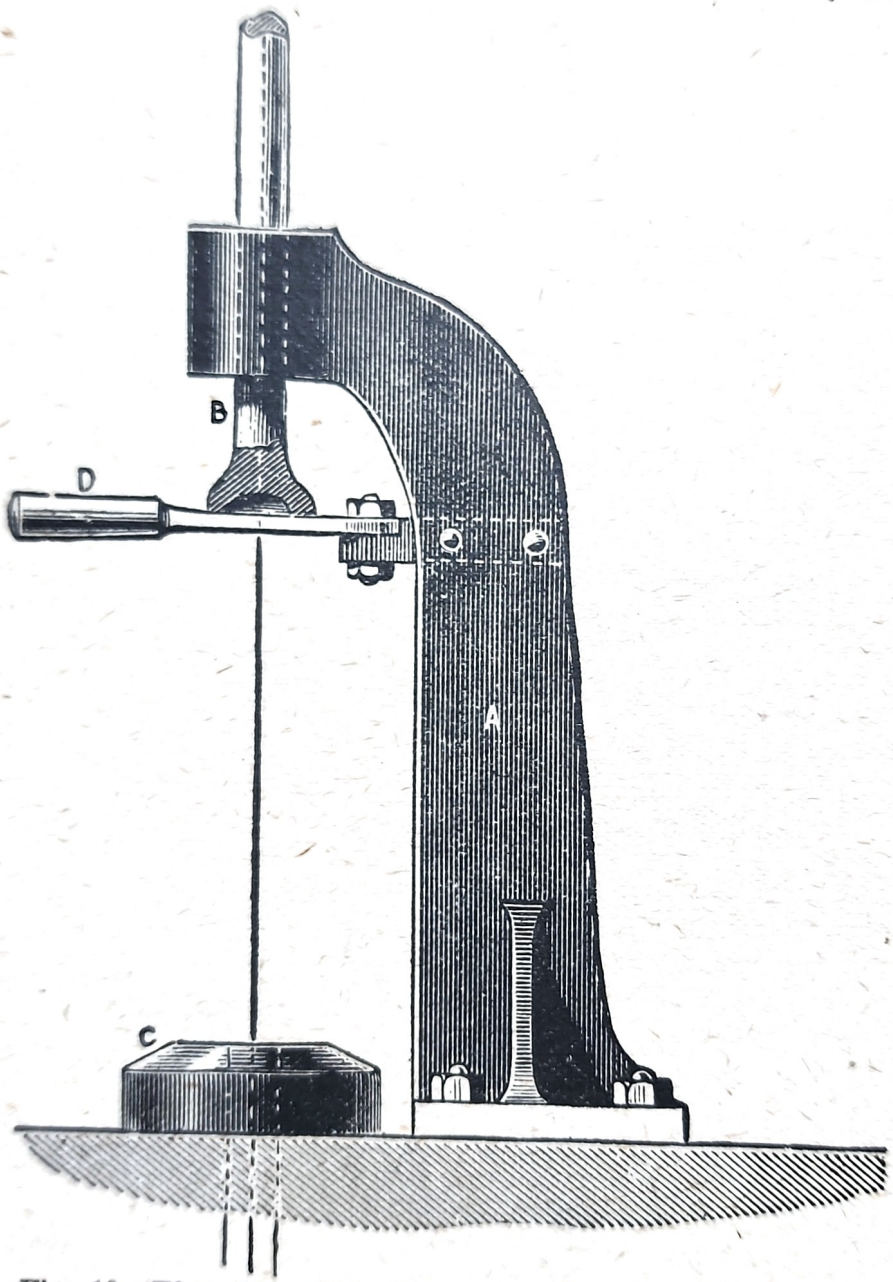

Fig. 16.—Elevation of Appliance for Rounding Bolt Heads.

slung in the crane, or be merely supported with the tongs, or balanced by other means.

Long rods and bars, when being cut off or

welded, require some support at the end farthest away from the smith. Support is also wanted when two rods are being welded by a single-handed worker; one rod is held by the smith, but the other has to be supported by some mechanical contrivance, which should be provided with some means of adjusting the height, to suit differences in the bulk or thickness of the work. Contrivances of this kind

Fig. 17.—Carrier for Bars.

are shown in Figs. 19 and 20, and both, of course, are portable. In the one shown by Fig. 19, two cheeks, A, of wrought iron, cut to the outline shown in the end view, and maintained at a definite distance apart with the stay bolts, B, B, are pierced with numerous holes, C, at different heights. Into any of these holes the bolt, D, can be inserted, carrying the loose roller, E, that supports the work.

In the second contrivance (Fig. 20), two uprights, A, are tenoned into a foot, B. Between the uprights

Fig. 18.—Carrier for Bars.

the forked piece, C, slides, and by the insertion of pins, D, D, in any pair of the series of holes in the uprights the height of the fork, and consequently of the work, is regulated.

Sometimes the support consists simply of a forked end screwed into a socket, and turned up or down with the hand; the adjustment of this appliance is more exact than in the others.

Another method of supporting heavy work is by means of an endless sling chain dependent from a

loose pulley, slung from a light jib overhead. This contrivance is often used simply for lifting work of considerable bulk from the fire to the anvil and back again. For heavier work a pair of pulley blocks are often slung from a jib, and then there is mechan-

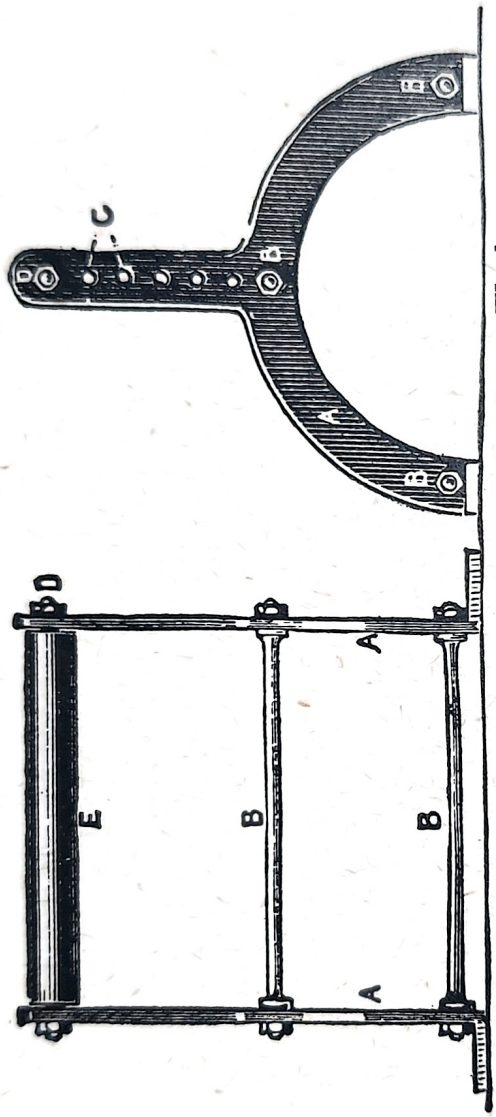

Fig. 19.—Adjustable Support for Long Work.

ical gain, and facility for raising and lowering the work as well.

Fig. 21 shows a simple and effective rig-up for manipulating heavy work. Use is made of the movable jib, which is an accessory to most forges. It is

pivoted against the wall, and upon its cheeks, A, A, runs the jenny, B, consisting of four wheels and carriage, with a depending hook, C, to which is attached a lever having a long arm, D, and a short arm, E. At the end of the short arm is a square nut, F, threaded to take a coarse, square-threaded screw, G, which passes up clear by the side of the crane. At the lower end of this screw is a swivel, H, through

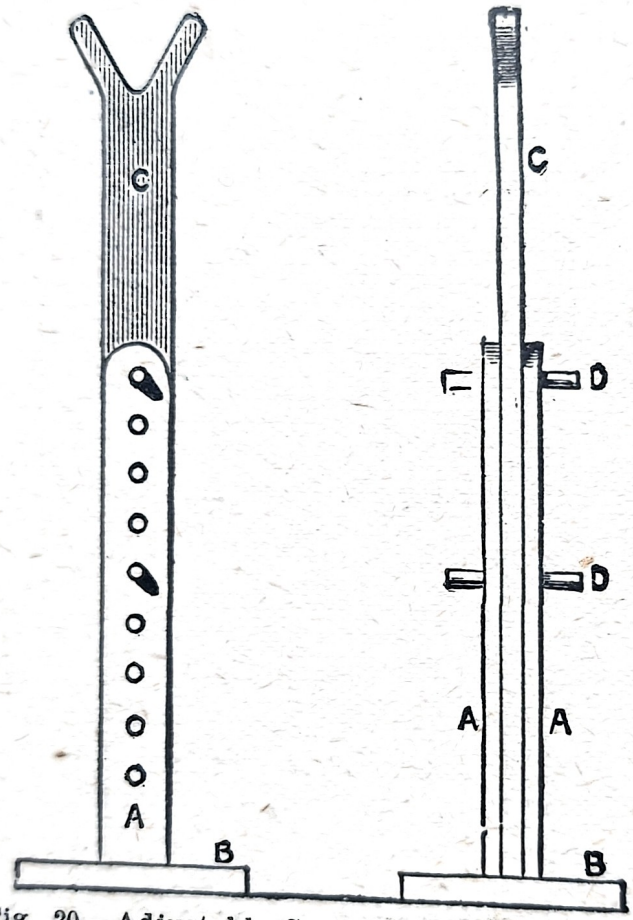

Fig. 20.—Adjustable Support for Long Work.

which the screw works, being turned by a lever passing through the hole in the boss at the lower end of the screw, G. From the lower end of the swivel depends the chain and clip in which the work is suspended. Adjustment of the height of the work can be made by turning the screw, G, the range of height being equal to the length of the screw, and

by pulling at the chain, J, at the long end of the lever. This latter, being rapid and immediate in action, is used during the manipulation of the work. The exercise of very little force, such as a man can

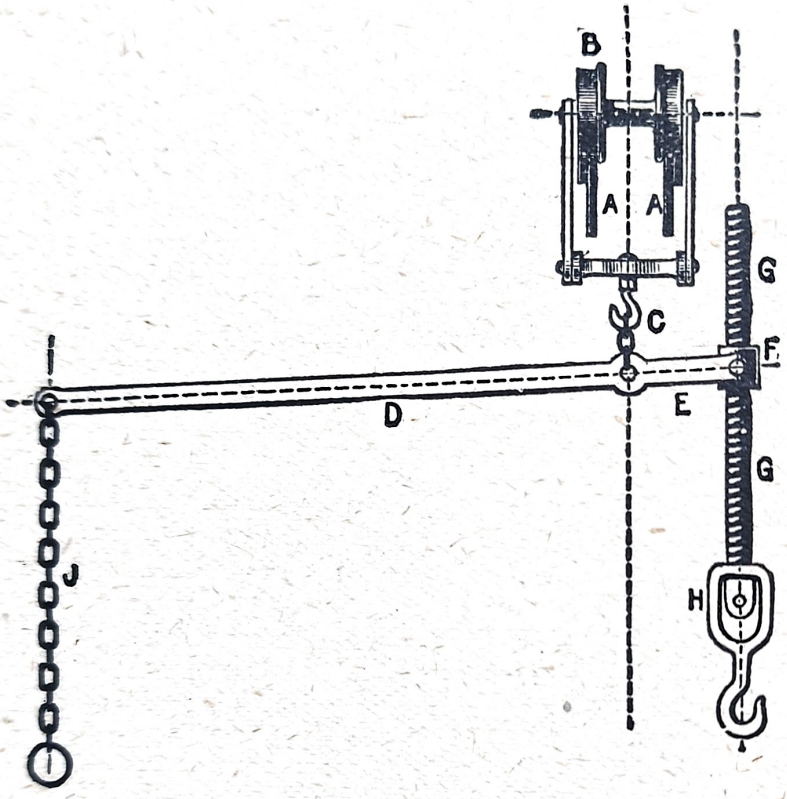

Fig. 21.—Apparatus for Lifting Heavy Forgings.

apply with one hand, is sufficient to raise and lower the work upon the anvil or the bending block, and to move it to any position required.

CHAPTER II.

HAND TOOLS.

The smith's miscellaneous small hand tools, though numerous, consist mostly of appliances for molding or shaping metal into diverse forms. Like the tools used in some other trades, many are made as occasion requires, and accumulate quickly.

The smith's hammers, other than power-driven, are of two kinds—the hand hammer and the sledge. The first-named weighs from ½ lb. to 1 lb., and generally is of the form shown in Fig. 22, with the ball

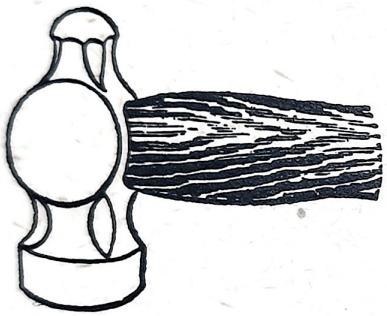

Fig. 22.—Ball Peen Hammer.

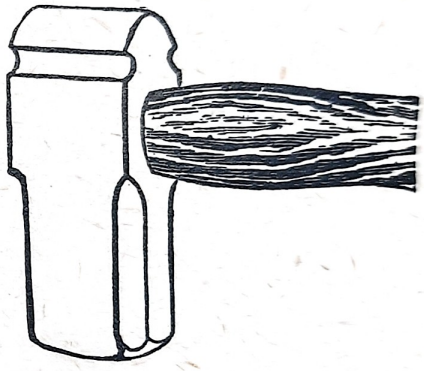

Fig. 23—Sledge Hammer.

peen. The cross peen hand hammer is used for fullering and drawing down. The flat face is used for striking heavy blows and for finishing surfaces. The sledges are of one of the two forms shown in Figs. 23 and 24, and weigh from 4 to 14 lbs., one of from 6 to 8 lbs. weight being about the average. Fig. 25 shows the method of wedging on the head to prevent it from flying off. Hammer handles should be kept in a dry place for several weeks previous to use; if they are not well seasoned, they shrink with the heat, and are apt to work loose on their heads.

The necessary firing tools are the poker, Fig. 26,

the slice, Fig. 27, and the rake, Fig. 28. Their uses are obvious.

Before any forging can be done, tongs are necessary. There are often a dozen tongs to a moderately well appointed forge, but it is not necessary to get them all at once; a few of the simpler and most necessary tongs will now be described. Each of these tools is made in several sizes to suit the various kinds of work.

Fig. 29 shows the hollow-bit tongs; enclosing and gripping the rod for a length of about 2 in., they take a very firm hold of both rods and bars. When there is a collar or other enlargement at one end of the bar, the pincer tongs, Fig. 30, are

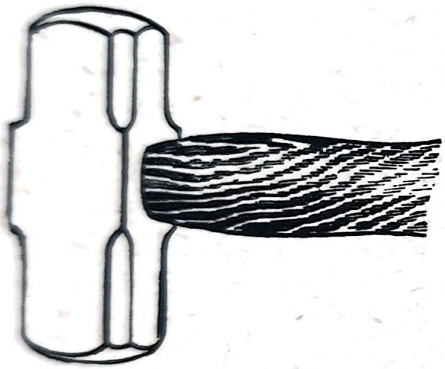

Fig. 24.—Sledge Hammer.

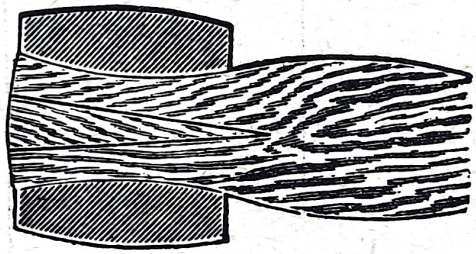

Fig. 25.—Section through Wedged Hammer Head.

sometimes employed to enable a firm grip to be taken; the jaws have V-notches, as shown in the end view. Fig. 31 shows tongs that are more generally useful; the elongation of the V-shaped jaws gives a stronger grip, and the rod or bar is less liable to shift sideways.

When a bar is so long that it cannot be held with these tongs, a crook-bit tongs (Fig. 32) is used; the jaws being turned aside permits the bar to pass alongside the handles on one side of the rivet. The lip serves to retain the bar in place, otherwise it would be apt to slip out sideways. With these four kinds of tongs work can be commenced on round

rods and square bars of iron. For other work there are other forms. The ring encircling the handles or reins of the crook-bit tongs is called a coupler,

Fig. 26.—Poker. Fig. 27.—Slice. Fig. 28.—Rake.

which is slid over the reins, and tightened by a tap or two with the hammer. The work is thus grasped

without the need of any further effort on the part of the smith.

For holding flat bars, tongs shaped like those

Fig. 29.—Hollow Bit Tongs.

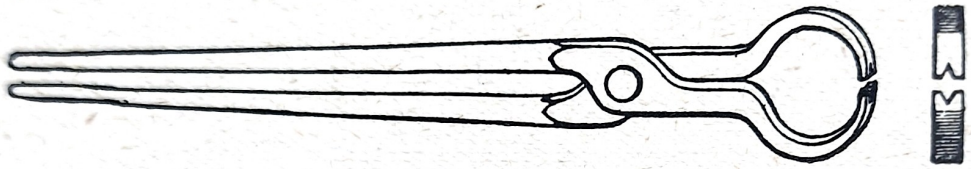

Fig. 30.—Pincer Tongs.

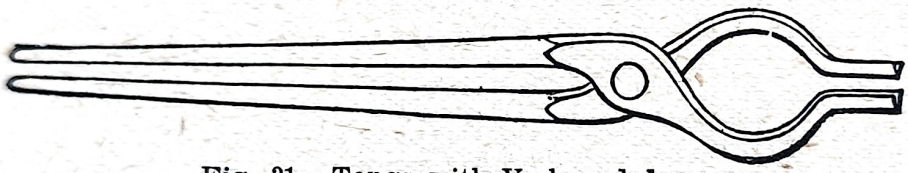

Fig. 31.—Tongs with V-shaped Jaws.

Fig. 32.—Crook Bit Tongs.

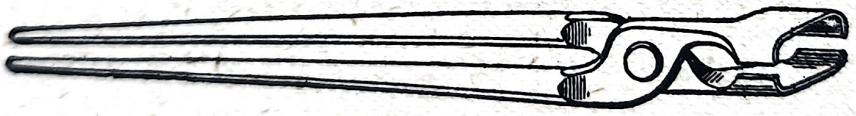

Fig. 33.—Tongs for Flat Bars.

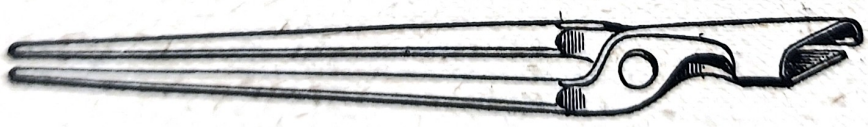

Fig. 34.—Tongs for Flat Bars.

shown at Figs. 33 and 34 are employed. In Fig. 33 the jaws are alike, and come into direct opposition. In Fig. 40 a flat jaw falls within the sides of the other. These are made in various widths and pro-

portions, the range of each pair being rather limited. For holding and manipulating rings, hoop tongs (Fig. 35) and pick-up tongs (Fig. 36) are employed.

When work is being reduced to final dimensions, it is necessary to check sizes by tools other than the steel rule. For flat rods the gap gauge is commonly used. It is of the typical form shown in Fig. 37, each gap being of a definite width, and differing from its neighbor by ⅛ in. or 1-16 in. Their depth is unimportant, but bears some proportion to width.

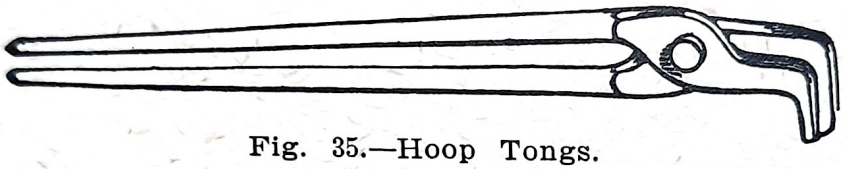

Fig. 35.—Hoop Tongs.

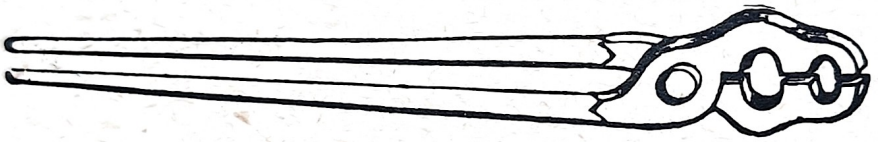

Fig. 36.—Pick-up Tongs.

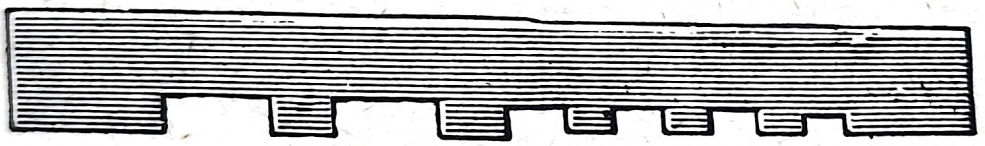

Fig. 37.—Gap Gauge.

These gaps, which are really fixed calipers, can be used in an instant to embrace and test the dimensions of a red-hot forging.

For circular work, calipers with long shanks are used. Fig. 38 shows a single caliper, whilst Figs. 39 and 40 are two forms of double calipers.

To cut a cold bar, it is nicked round with a cold set (Fig. 41). The bar is laid across the anvil with the chisel-edge upon it, and the chisel, being struck with a hammer, nicks the bar. The bar is rotated slightly and another blow struck, and so on rapidly until there is a sharp indentation all round the

bar. Then it is struck sharply across the edge of the anvil and snapped in two at the nicked section.

A hot-set (Fig. 42) is used if a bar is divided while red-hot, and the smith holds it in place while the hammer-man strikes it. The set is driven in

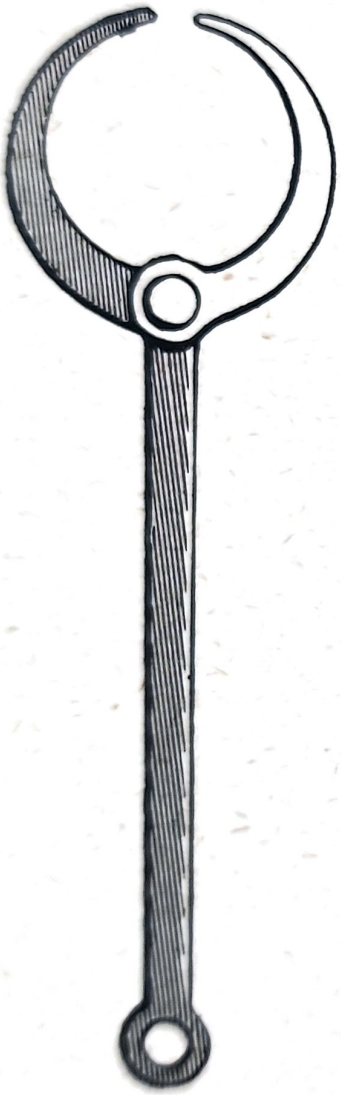

Fig. 38.—Single Caliper.

Fig. 39.—Double Calipers.

deeply, and several blows are given at one spot; and by the time the bar has been turned completely round the set has almost or entirely severed it. In use the set becomes hot, so that it would be liable

to lose its temper and become soft; therefore, after every four or five blows on the hot iron, the smith dips it into water to cool it. The hot sets are often provided with handles differing from those of the swages—that is, they are like hammers, but without

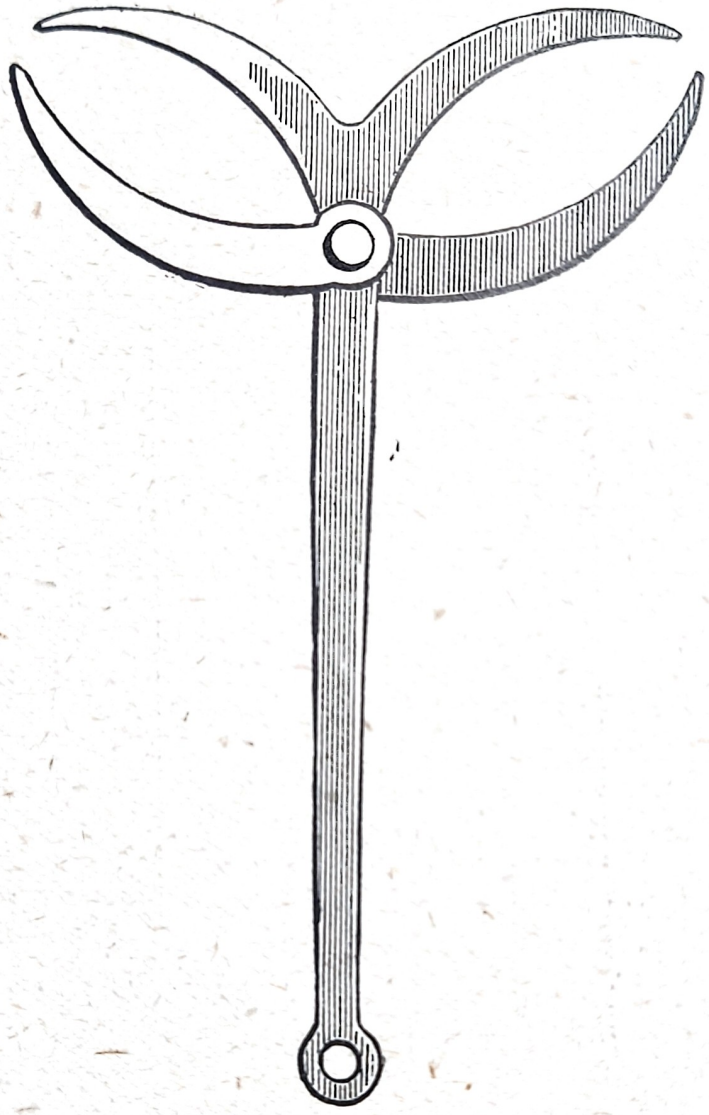

Fig. 40.—Double Calipers.

wedges, which would shrink and become loose, because they are subjected to more heat. When the handle becomes loose, striking its butt end upon the anvil jumps the set down to a firm hold, ready for immediate use. Sometimes they are provided with

iron handles, or with withy handles as shown in Fig. 41.

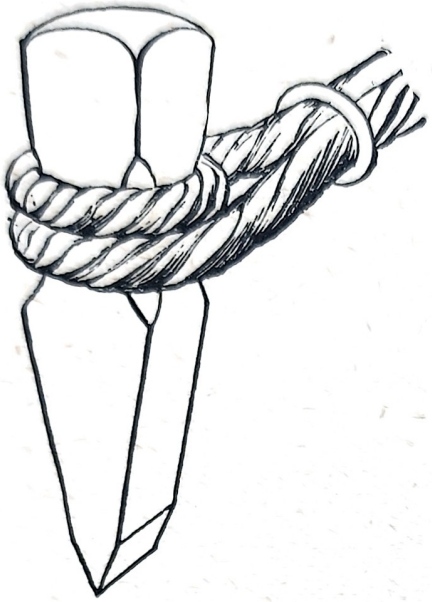

Fig. 41.—Cold Set.

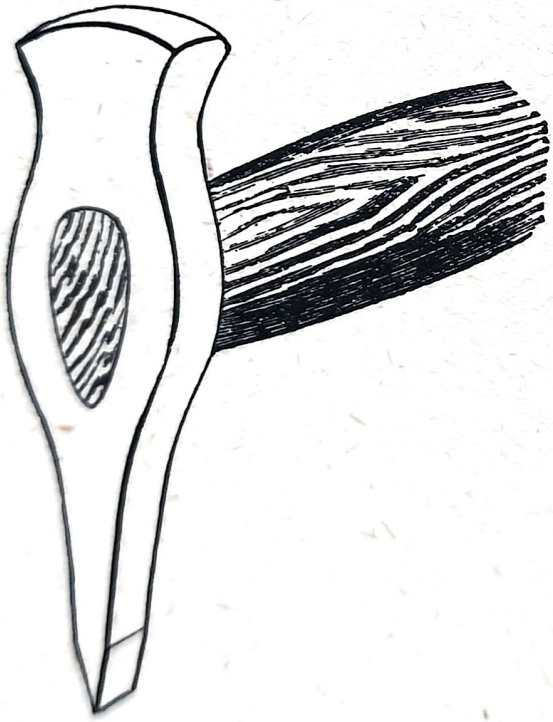

Fig. 42.—Hot Set.

A smith working single-handed when nicking bars uses the anvil cutter (Fig. 43). It is essentially a

chisel, having its edge uppermost and a shank fitting into the square hole in the anvil; a bar laid upon it and struck with the hammer is nicked on the under side, and rotating and striking it with the hammer will have the effect of nicking it all round.

The knife tool, Fig. 44, and the curved tool, Fig. 45, are used for cutting lengths off iron bars.

Swages of many shapes are used for a variety of purposes which will be duly explained. Top and

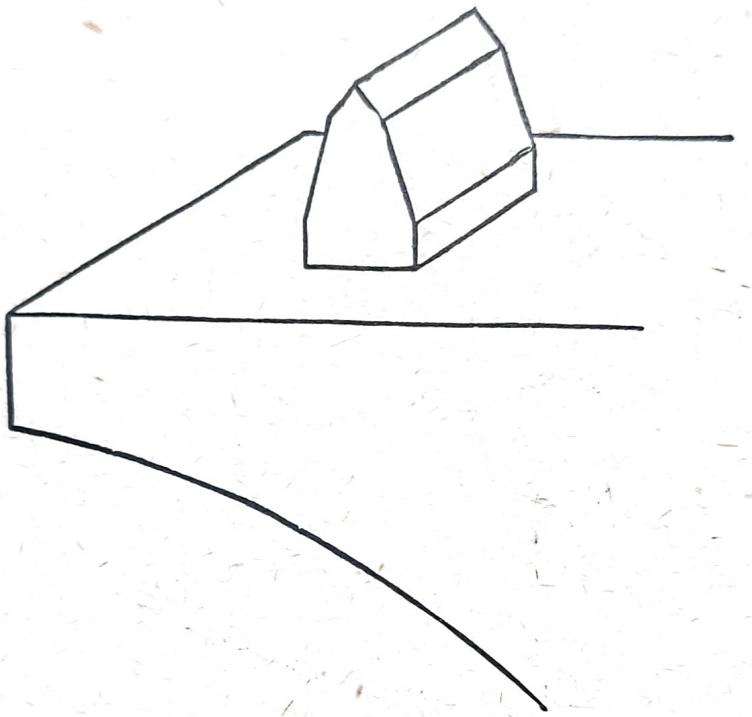

Fig. 43.—Anvil Cutter.

bottom swages are illustrated respectively by Figs. 46 and 47.

A bottom swage like Fig. 48 is very useful, both for bolt making and for general work. Using this, a gradual reduction in diameter can be made without the trouble of changing the separate single bottom swages. A swage for finishing collars is illustrated by Fig. 49.

In the spring swages, Figs. 50, 51 and 52, the top swages guide themselves, and the work can be held in

position and hammered to shape by one operator. The difference between the three is that, whilst Figs.

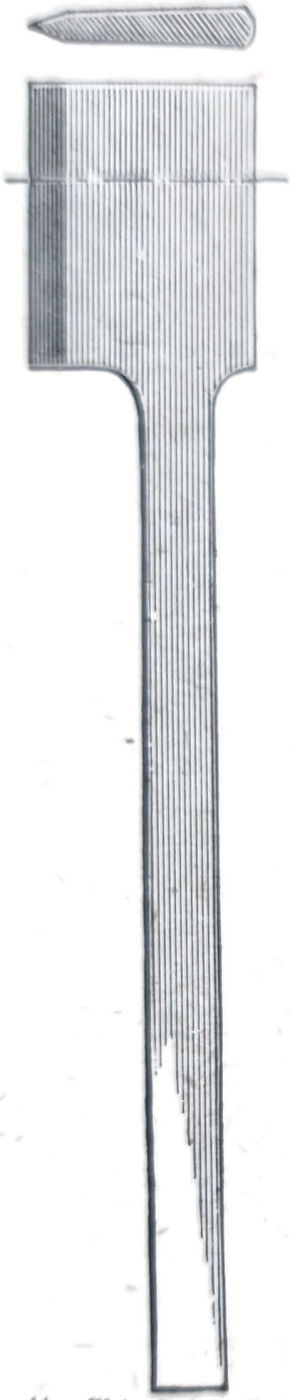

Fig. 44.—Chisel for Cutting Iron Bars.

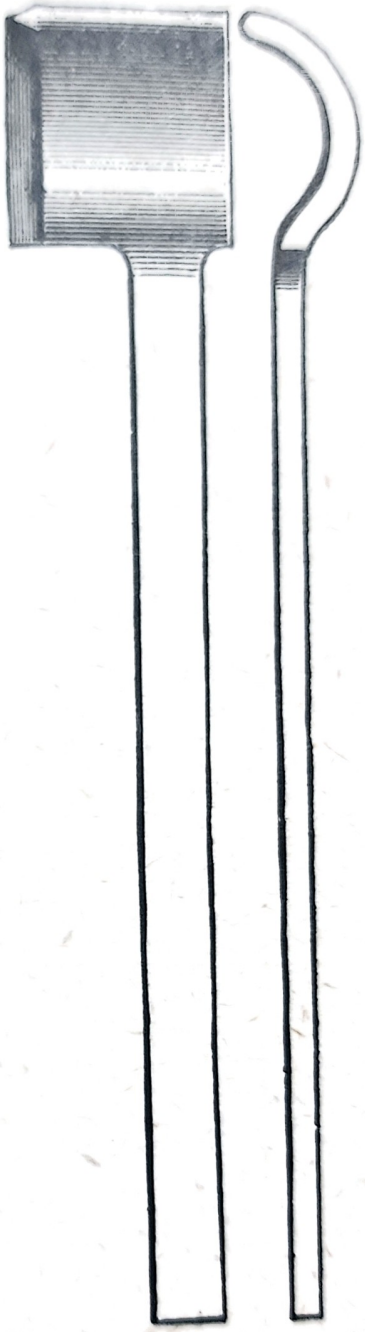

Fig. 45.—Chisel for Cutting Circular Ends.

50 and 51 each take one diameter of iron, Fig. 52 will take three different sizes. The top and bottom

faces of two, it will be noted, are made flat for use with the hammer, while in Fig. 51 the lower swage has a pin to fit into the anvil, and the upper swage is formed to be struck with the sledge-hammer.

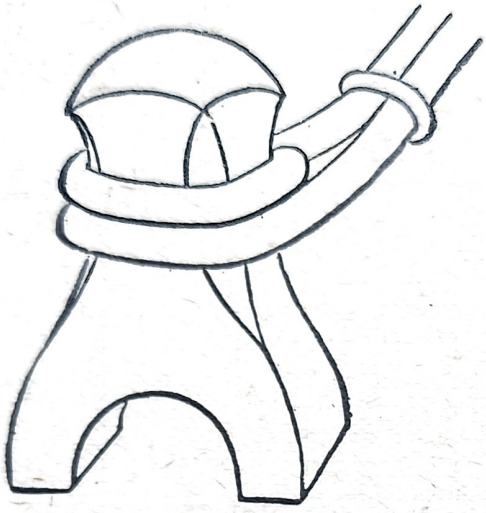

Fig. 46.—Top Swage.

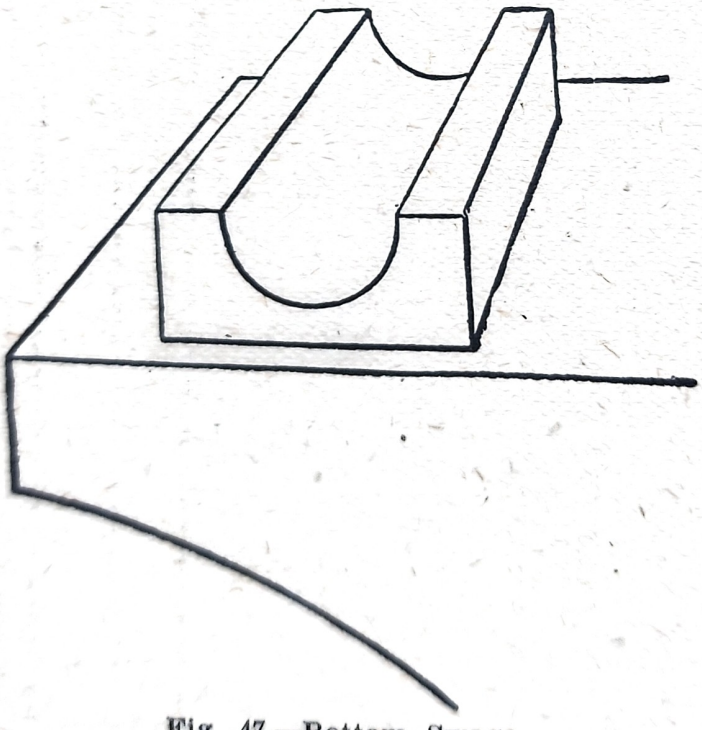

Fig. 47.—Bottom Swage.

The angular swage, Fig. 53, is used in shaping and welding hot metal. The angles support the sides of the metal whilst being hammered, and the work

is performed more quickly—an important matter in welding. With this tool, a top swage can be used if desired, or the sledge or steam hammer by itself.

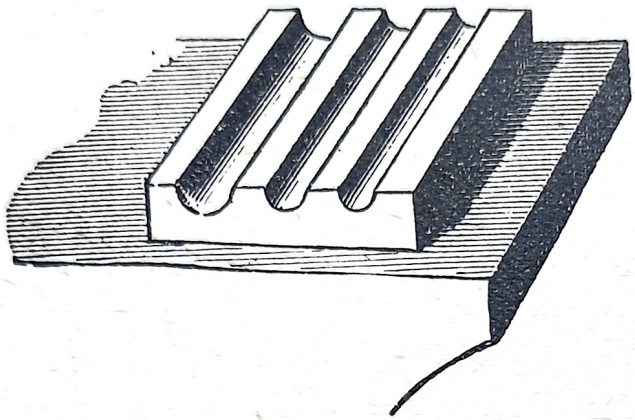

Fig. 48.—Bottom Swage.

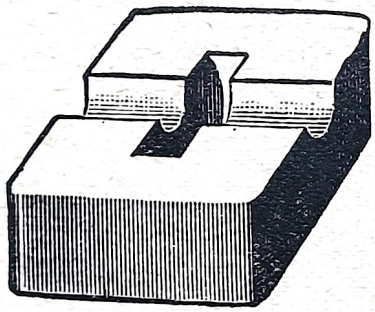

Fig. 49.—Swage for Collars.

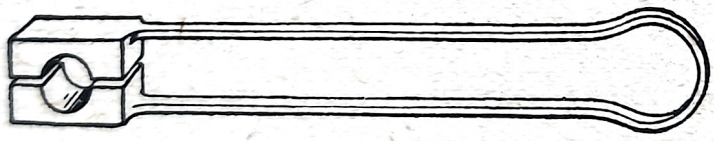

Fig. 50.

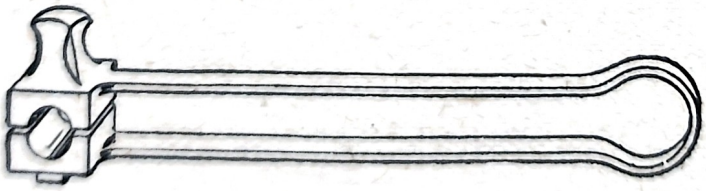

Fig. 51.

In Figs. 54 and 55, similar swages are shown as forming bolt-heads.

The common swage block, Fig. 56, is an appliance

without which no smith's outfit is fairly complete. Its body is pierced with numerous holes—round, square and oblong—and its edges are provided with grooves of various sizes, in circular and V forms. The block is used lying on its side, as a bolster,

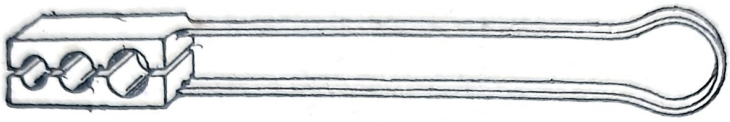

Fig. 52.—Spring Swages.

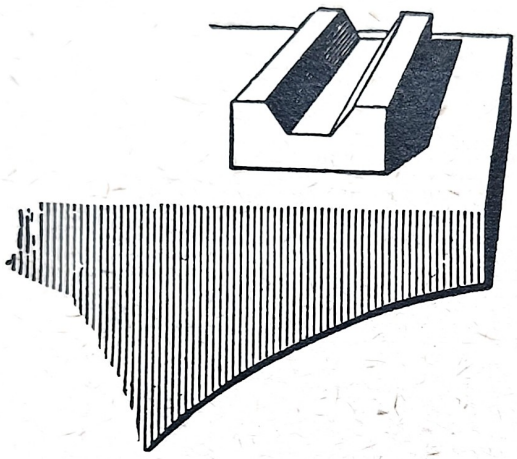

Fig. 53.—Nut Swage on Anvil.

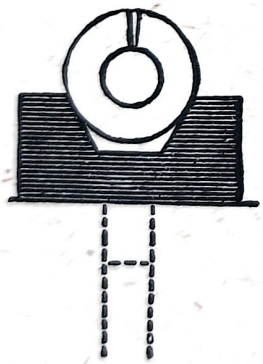

Fig. 54.—Bolt Head Laid in Bottom Tool.

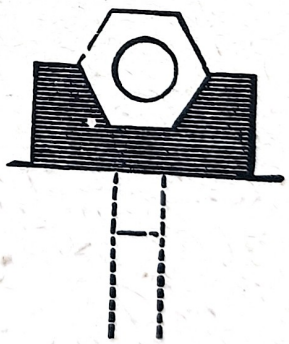

Fig. 55.—Bolt Head Shaped in Bottom Tool.

upon which holes are punched and drifted, and as a heading-tool, upon which shouldered work is finished. When laid upon one of its edges, the grooves serve as bottom swages for circular, hexagonal and rectangular work.

The stand upon which the swage block is mounted may consist of upper and lower cast-iron frames,

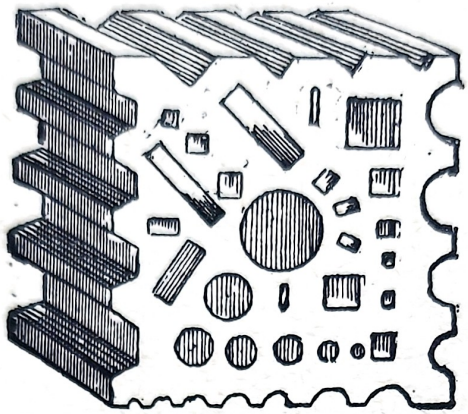

Fig. 56.—Swage Block.

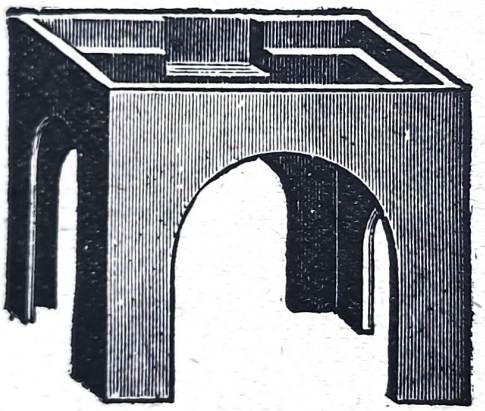

Fig. 57.—Swage Block Stand.

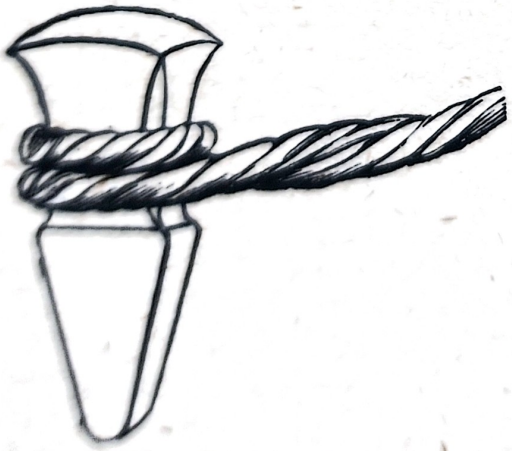

Fig. 58.—Top Fuller.

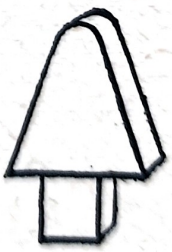

Fig. 59.—Bottom Fuller.

with the upper one provided with strips, enclosing the block. The two frames are held together by

four shouldered wrought-iron pillars, whose pins pass through holes cast in the frames, and are riveted over at top and bottom. Fig. 57 shows a stand.

An essential tool is the fuller, of which four forms are here illustrated; Fig. 58 shows an ordinary top fuller, Fig. 59 the bottom fuller, Fig. 60 the round-faced fuller, and Fig. 61 the hollow fuller. Another form of hollow tool is shown by Fig. 62 as finishing a ring on a V-block. These tools enter into much of the smith's work, as will be made apparent as the subject is pursued.

The flatter, Fig. 63, is held by the smith whilst

Fig. 60.—Round-faced Fuller.

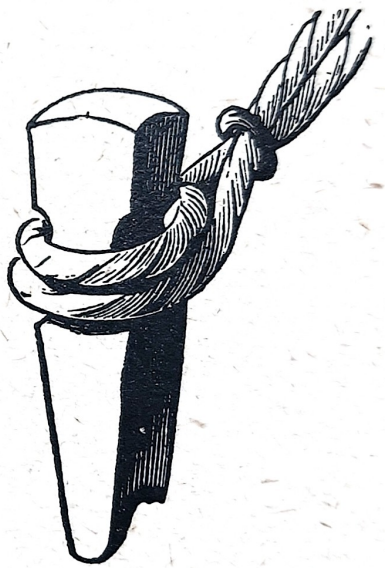

Fig. 61.—Hollow Fullering Tool.

the hammermen strike it with sledges. The cup tool, Fig. 64, is used in the same manner as the flatter.

Punches are circular, square, oval, oblong, and wedge-shaped, and have handles of hazel or iron. A punch, Fig. 65, and a bolster, Figs. 66 and 67, are often used together, the punch, by means of hammer blows, being driven through the red- or white-hot metal placed over the bolster.

Drifts are used to finish holes that have been

punched smaller than the finished dimensions, when facilities for machining are not available. They are taper, as in Fig. 68, or parallel tools, having circular, square, oblong, elliptical, or polygonal cross sections, corresponding to those of the finished holes. There is scarcely a limit to the forms in which they may be made and used. Drifts are smooth, and, being driven

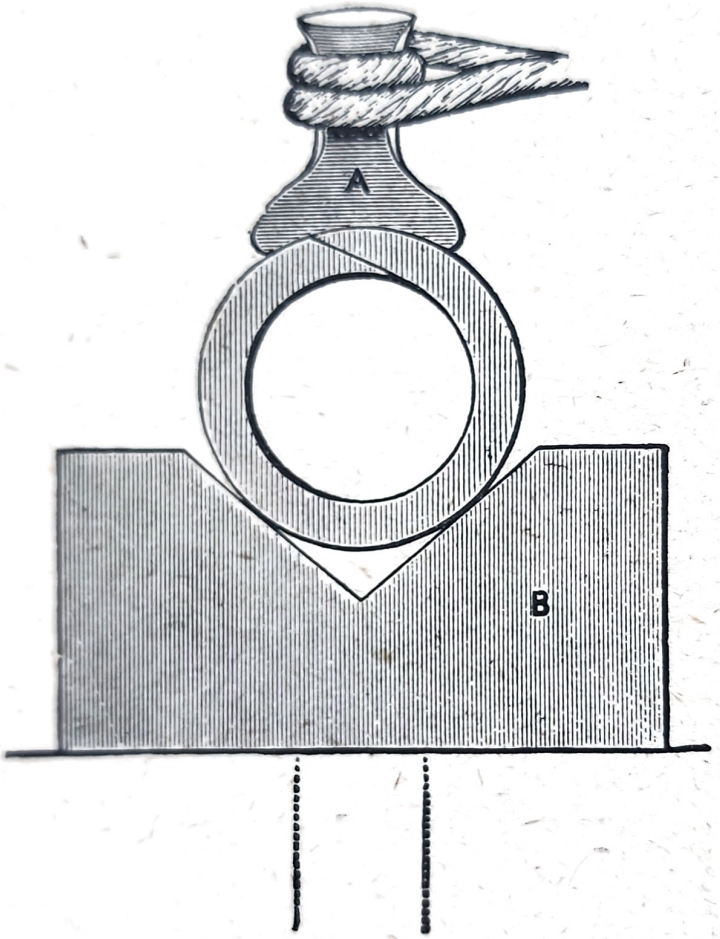

Fig. 62.—Finishing Ring on V-block with Hollow Tool.

through the punched holes, enlarge, shape, and smooth them while the metal is red-hot. Two drifts are often employed; one considerably tapering, so as to enlarge the punched hole; a second, the filler, or filling-in piece, or mandrel, very slightly tapering, for imparting the precise finished dimensions.

Smooth drifts are rarely parallel; if they were,

their withdrawal from a hole would be a matter of difficulty; the sides should taper not less than from two to four degrees.

The cutting drift partakes either of the nature of a sharp punch, or of a file. It does not open out

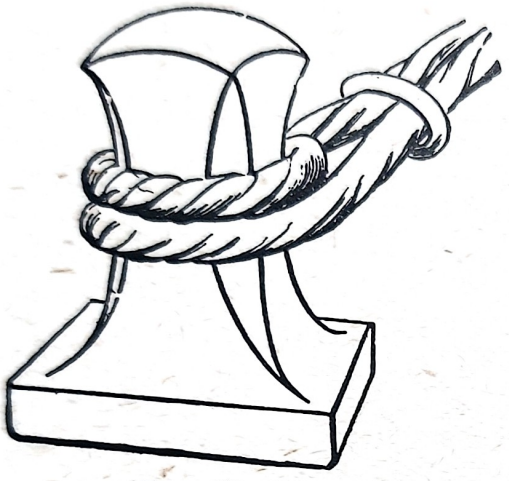

Fig. 63.—Flatter.

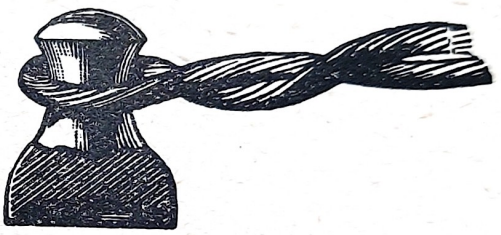

Fig. 64.—Cup Tool.

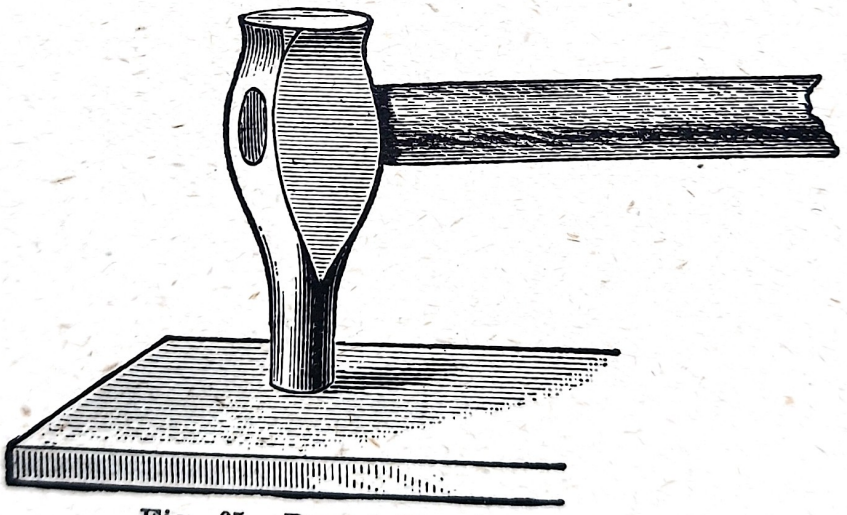

Fig. 65.—Round Punch on Thin Bar.

the hole by pressure, and does not remove a large quantity of material at once; it merely smooths and finishes a hole already nearly to shape and size. Fig. 69 shows a drift for shallow holes, and Fig. 70 for deep ones; they are shaped with files from suitable blanks, and then tempered to a color ranging

from brown to purple. Toothed drifts for fine work have the teeth closer together; for coarse, rough work, they are spaced farther apart. They are beveled to allow clearance for the chips, being the equivalent of backing-off in other cutting tools. For hard metal the angle between the cutting edge and

Fig. 66.

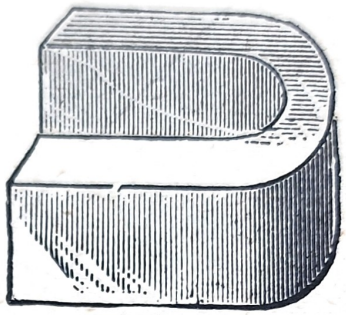

Fig. 67.

Bolsters.

Fig. 68.—Tapered Drift.

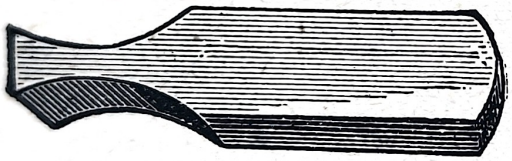

Fig. 69.—Drift for Shallow Holes.

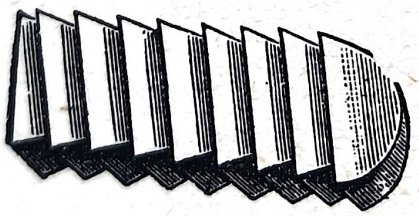

Fig. 70.—Drift for Deep Holes.

the face is greater than for softer metals, thus following the usual practice in all cutting tools. Oil should be supplied to the edges of the drift, and of the hole when driving it in, and the work should be bedded firmly on a block of metal; and care must

be taken that the drift is driven straight. If the hole is deep, the drift must be withdrawn once or twice for clearance of chips. If the hole to be drifted is much smaller than the finished size, it will be necessary to enlarge it by chipping with a chisel.

Drifts with teeth are used for making round holes into square, oval, hexagonal, etc. It is better in these cases to work one-half the hole at a time. Thus, in drifting a round hole into a square one, one-half the round hole would be filled with a half-

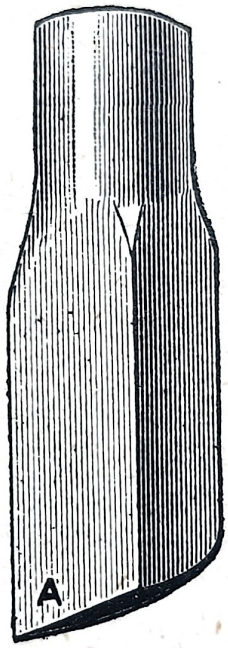

Fig. 71.—Drift used in Smoothing Holes.

round plug, and a flat drift used to operate against the other half of the hole, little by little, thin backings being interposed one after the other. When one-half of the square is shaped, it is filled up, and the other half treated similarly. An elliptical hole is shaped in a similar way.

The drift is also serviceable for holes that do not pass quite through the material. As an example, for a rectangular hole to be smoothed in one direction, the drift shown in Fig. 71 could be used. The face, A,

would remove a thin shaving. To take a second cut a thin strip of metal would be placed behind the drift; to take a third cut, an additional thin strip; and so on.

For drilling large holes, the ratchet-brace is a good tool. It can be fixed either upon a bench in a permanent position, or where wanted on work in hand. A press-drill thrust down with a lever is also a common appliance in country shops. For a shop where much drilling is done, a double-geared hand or power drill is more efficient.

Dies are used by the smith when the initial cost of making them is likely to be repaid by the increased convenience and time saved. They will be described later.

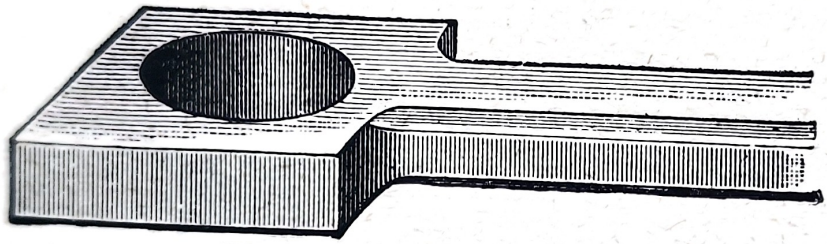

Fig. 72.—Heading Tool.

The heading tool, Fig. 72, is used for finishing the shouldered ends formed on round bars. The hole should be sufficiently large to take the bar whose end it is required to true.

Small tools—as tongs, swages, fullers, flatters, punches, and such like—accumulate in large numbers, and litter the place unless proper methods are employed to keep them in order. Commonly, racks are fixed against the wall by the side of the forge. These are stout iron bars, supported parallel between uprights, at a distance of from 6 in. to 8 in. from the wall; the shanks or handles of the tools are dropped between these bars, their enlarged portions resting upon the top edges. Tool racks are formed against the wall by driving two uprights into the

ground at each end, and riveting the horizontal bars of iron to these. The uprights and the bars are of flat iron—say, 2 in. by ½ in.—placed edgewise.

For the lightest tools, handled with withies, or with round rods, it is sufficient to employ as racks short lengths of round rod riveted into flat bars. The flat bars are then secured to vertical uprights driven into the ground and leaning against the wall, and the rods stand out like spike nails. Upon these the light tools are hung by their handles. The flat bars may measure 2 in. by ½ in., and the rods be of ½-in. iron, 5 in. or 6 in. long. These lighter racks should be placed above the racks of parallel bars just previously described.

Another method is to have an oblong open bench or stand of wood rigidly framed together. The top is crossed with bars or rods, leaving open spaces, in which the shanks or handles of the tools drop. Unless there is plenty of floor-room available, this is not so good as the rack, which occupies scarcely any floor-space.

For the heavier appliances used with the steam and other hammers, stands of a different kind are also used. Thus, two cast-iron standards of A form, with three or four pairs of internal brackets, carry between them stout deal planks, which are bolted to the brackets. Upon these deals the heavy spring swages, die-blocks, etc., are laid side by side, the lighter on the top shelves, the heavier beneath, ready to hand.

CHAPTER III.

DRAWING DOWN AND UPSETTING.

Before attempting to execute either of the processes of drawing down and upsetting dealt with in this chapter, it is necessary that the fire in which the iron is to be heated be properly made. The formation of the fire is of far greater importance than may be supposed.

The "stock" is the term given to the mass of hard-caked coal on a smith's hearth, within which the heat is confined; and it also in some degree forms a reserve of fuel. But its primary purpose is to prevent radiation of the heat, and to cause its concentration upon the work in the hearth. If it were not for the stock, much of the heat would go up the chimney, and the work also would be oxidized more rapidly than it is, by reason of its partial exposure to the air. The size and shape of the stock evidently depends on those of the work. The stock consists of two portions—one lying against the tuyere and hearth-back, the other placed opposite to the first in the direction of the coal and water bunks, the work lying midway between the two. The only portion of the fire that is replenished to any considerable degree, in the course of a day's work, is that central portion. The stock, though highly heated, does not burn away sensibly, because it is protected from the direct action of the blast, and the upper portions are kept damp. Yet the inner faces, being in direct contact with fuel supplied from time to time to the central part of the fire, are at a glow with heat.

To make a fire, therefore, the stock is first built at the back and front of the hearth, and beaten hard with the slice or with the sledge, the choking of the tuyere hole being prevented by passing an iron rod temporarily into it. The fire is then lit in the central portions with a handful of shavings and a little coal, assisted by a gentle blast.

Forgings of unequal sectional area are formed either by drawing down, upsetting, or welding, or by a combination of the three processes. Generally, the choice between these three methods is not made because one is essentially superior to the other regarded simply as a question of ultimate results, but because under given circumstances it either involves less work or economizes material, or is the only way possible with material that happens to be in stock, or because there are odds and ends that it is desirable to use up; or, lastly, because it is the best method available with the tools and help at the disposal of the smith. The alternative, therefore, is commonly one of expediency.

It is often, however, a question of relative dimensions. If the difference between the enlarged and the reduced part is very great, neither drawing down nor upsetting would be resorted to, unless for some exceptional reason, but welding would be employed. The same holds good in other forging; as, for example, in the case of eyes. An eye having a small hole and much metal around it, as that of the tie-rod of an iron roof truss, would have that end forged solid, and the hole punched through. But an eye having a large hole and relatively little metal around it, and so possessing more the character of a loop, would be bent round and welded. An eye of medium thickness may obviously be made in either fashion.

To draw down a piece or iron, proceed as follows: Suppose the portion marked A, Fig. 73, has to be drawn down from a bar originally of the size of

B. The bar is laid across the edge of the anvil in a slightly inclined direction, and nicked at C, Fig. 74, with a top fuller. If both sides of the bar have to be drawn down, then a bottom fuller would be inserted in the anvil in opposition to the top fuller, and the bar would be nicked as in Fig. 75. Chisels

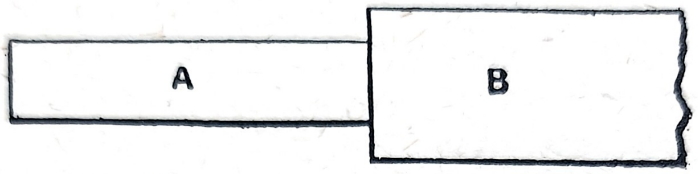

Fig. 73.—Square Bar Drawn Down.

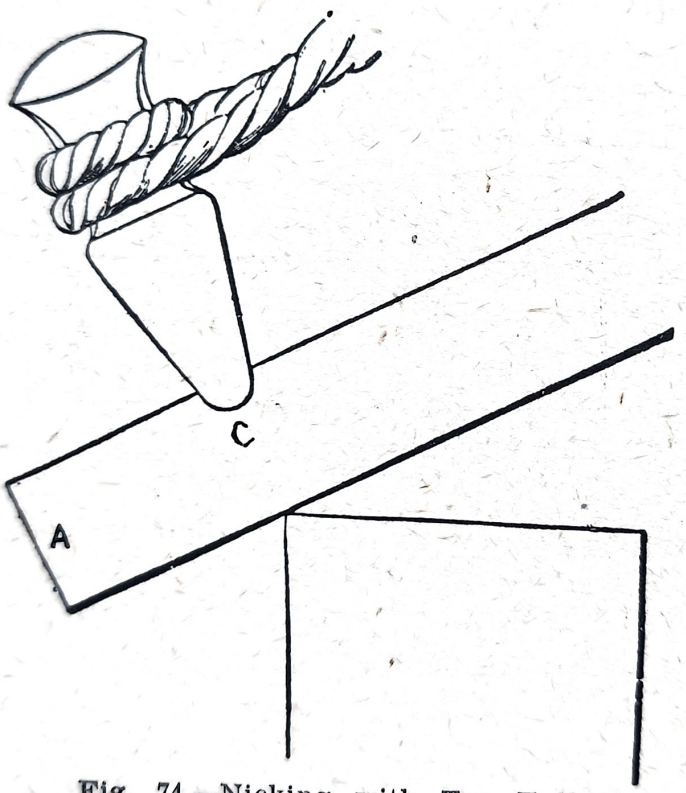

Fig. 74.—Nicking with Top Fuller.

or sets are not used in such nicking, for these would divide the fibers of the metal, while the round-faced fullers simply alter their direction without breaking their continuity.

The preservation of the continuity of the fiber is of primary importance in forged work, so that what may appear to be roundabout methods which give

much extra trouble will often be resorted to in order to preserve that continuity. Fiber or "grain" should never be severed. Few of the tools used by the smith for shaping to outline have absolutely square edges; they are all more or less rounding. Thus the continuity of the fiber is preserved, however it is bent and twisted. A bar of iron held in the vice and bent until it is doubled shows on the outside radius the torn ends, which look like bundles of vegetable fiber, and not unlike torn animal muscle. A specimen torn asunder in a testing machine has its fibrous structure still more apparent, though not so clearly as in the bending process, in which the outer skin will present a most characteristic striation or shriveling in the longitudinal direction.

Fibrous iron may readily be changed into a weak

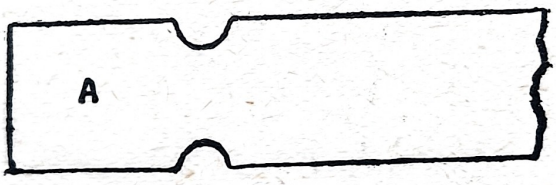

Fig. 75.—Bar Nicked with Top and Bottom Fullers.

crystalline material by nicking with a sharp tool, or by excessive hammering. A bar of iron, nicked round, and broken off suddenly, shows fractured surfaces as highly crystalline as those of cast iron. This clearly proves the necessity of making fullers, and other shaping or molding tools, with edges rounding.

When the work has been nicked with the fuller, the metal along A (Figs. 73 and 75) is drawn down or thinned by a succession of blows from the hand hammer or sledge, with or without previous fullering. When fullering tools are used, the top fuller would be employed singly if only the one face requires reduction, or in pairs, one above the other, if both faces have to be drawn down. The effect is

that a succession of depressions are formed upon the surface of the spread-out work with ridges between, and these have to be obliterated with the hammer.

Fullering and hammering not only lengthen the bar, but also spread it sideways. If the bar is to be equal-sided, the widening has to be prevented by rapidly hammering the sides alternately with the faces. After every few blows are given on the faces, the smith turns the bar quarter round during the brief interval between a couple of blows, and the iron receives several blows upon the edges as a corrective to those on the faces, and its equal-sidedness is thus preserved during the process of drawing down. By practice, this rapid changing of the faces on the anvil is accomplished without damaging the rectangular form.

In drawing down, whether with fullering tools, or with the hammer alone, as is frequently done where the reduction in area does not amount to much, the process of thinning always commences at the end of the iron farthest from the smith, and proceeds towards himself. One inch and a half or two inches is drawn down at a time, and the work is thus rendered easier than if a larger surface were taken at once.

When the iron is first roughed down, its surface will not be smooth, though a good smith can impart a very fair finish to a flat surface by the hammer alone. The hammers should strike so as to bruise the work as little as possible. There is a knack in using the hammer so that its edges will not mark the work, the blow being given by the central rounding portion of the face only. Striking fair with the middle of the hammer face, each mark serves to partly obliterate others, and leaves a very smooth surface, only slightly wavy. This is all that a smith working single-handed can effect by way of finish. With the assistance of a hammerman the surface

can be smoothed more effectually by means of a flatter, which is held with the right hand of the smith, and slid in turn all over the surface of the work while the hammerman strikes it with the sledge. Thus finished, the work is left very smooth.

In drawing down a round bar the process is the same in principle, but slightly different in detail. The rod will be nicked round with a fuller and drawn down under the hammer, beginning as before at the end farthest from the hand. A fullering tool is not used for extending the metal, which is done with the hammer only, and the rod is rotated between each hammer blow. Toward the close of the operation, smoothness is imparted by means of swages, the work lying in a bottom swage of nearly semicircular form, see Fig. 76, which shows an anvil swage fitted into the hole in the anvil, while blows are struck upon the rod's upper surface with a hand hammer, if the smith be single-handed, or, if the smith has a striker, with the sledge upon a top swage the counterpart in form of the bottom. In Fig. 76 A indicates the top and B the bottom swages, with the bar of iron, C, between them; D is the anvil.

By means of suitable spring swages, previously described, a smith, working single-handed, can sometimes make use of the top as well as of the bottom tool.

With a steam hammer this work of drawing down and finishing is very much simplified. It is then not even necessary to use top or bottom fullers, for, having marked the position of the shoulders on the bar, the smith lays the bar on the anvil of the steam hammer, and draws down the work directly between it and the tup or hammer, turning the bar quickly during each period of ascent of the tup. If the bar is of large size and of considerable length, the drawing down will still have to be done in short lengths,

two or three inches from the end being drawn down first, and the bar being then thrust farther along, and the succeeding portions drawn down. The bar is always held perfectly flat, and the hammer finishes at once.

For rod work, top and bottom swages of the

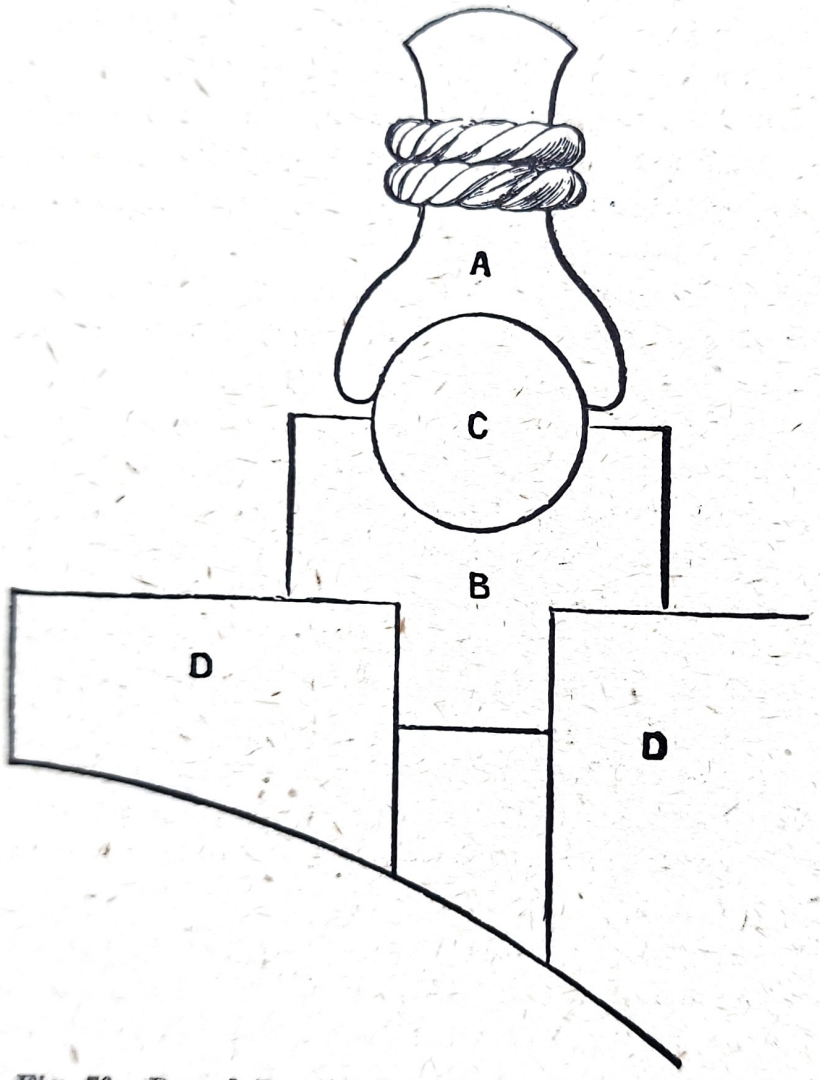

Fig. 76.—Round Bar between Top and Bottom Swages.

spring type are placed under the tup at the finishing stage. The rod is first drawn down roughly between the anvil and the tup, being rotated rapidly between each blow, a rudely circular form being imparted or preserved simultaneously with the proc-

ess of drawing down. Before the reduction is quite complete, the spring swages are placed on the anvil, held by an attendant, the work inserted between them, and rounded and finished by a few final blows of the tup on the top swage—the work still being revolved during each period of ascent of the tup.

While these processes are being carried out, and with the iron at a red heat, a scale of oxide forms rapidly. The larger the forging, the greater the quantity of the oxide formed. This should be brushed away with a switch of brushwood as fast as it forms, otherwise it will be driven by the hammer blows into the surface of the work, and form a rough scale, which is afterwards both unsightly and a hindrance to easy tooling in the vice or lathe. Where the forgings are large, a man stands by the steam hammer and brushes away the scale after every half-dozen or so blows. At the anvil the striker or the smith knocks the scale off immediately the iron is removed from the fire, and afterwards as often as it may be required.

To judge the length of iron to be allowed for drawing down is not difficult to a practiced smith. Few trouble to calculate in figures the length required. Yet, when working the best and most expensive qualities of iron and steel, it is as well to bear in mind a rule of simple proportion. The original section of a bar bears the same proportion to a given reduced section that the length of the latter bears to that of the former. Thus if a bar originally 3 in. square has to be reduced to an inch square, one inch in length of the 3-in. bar will be taken for reduction to a 3-in. length of one inch square. If the reduced portion is tapered, or of unequal and varying dimensions, then the mean of the various sectional areas must be taken. Additional allowance must be made for ragged and perhaps burnt ends, and a trifle for inaccuracy in cutting off.

The time different smiths will be occupied over a given piece of work differs greatly. A smart smith will always do as much work as possible upon a forging in a single heat. While his iron is in the fire, he will mentally go through the sequence of operations, and see that whatever is required is at hand, and when the iron is on the anvil he will strike quickly while the iron is hot. In some examples to be given, the number of heats in which work ought to be forged will be stated approximately.

Upsetting, or jumping up, is one of the alternatives of drawing down. By this method the metal is knocked or jumped up into a mass larger in area than the bar itself. Upsetting is a slower and more laborious process than drawing down. A smart smith will draw down several inches of bar at one heat; but to upset a very moderate mass of metal will require several heats. Hence it is not possible to treat in this way any very large-shouldered portion; in this case the plan is to weld on a ring or collar, or a solid mass of metal, according to circumstances. Except the iron be cut off sufficiently short to go endwise under the hammer, the use of this tool is not possible in upsetting. However, the monkey, or swinging pendulum hammer, fulfils the purpose of the hand hammer.

The method of upsetting to form a collar, A (Fig. 77), upon the end of a rod whose original section is that of B, and without welding the collar on as a ring, is as follows: The end which is to form A is enclosed in the fire, but no more of that end is heated than the precise amount required to be upset; that portion of the rod which joins it is kept quite cool and black by heaping damp coal around it. The end is then brought nearly or quite to a welding heat, and taken from the fire. Sometimes on removal from the fire, and just before upsetting, the extreme face of the heated end is dipped into the water trough

to chill it, and so the better to prepare it to resist the blows of the hammer; but this is not always done.

The actual upsetting is performed in one of sev-

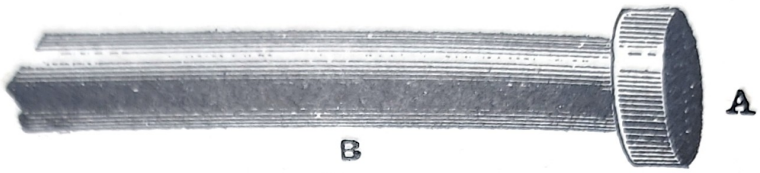

Fig. 77.—Bar with Collar on End.

eral ways. The bar may be held in both hands (Fig. 78) in a vertical position, and the white-hot end jumped down repeatedly upon the anvil face, or

Fig. 78.—Jumping Bar Vertically.

Fig. 79.—Upsetting Bar Horizontally.

upon the plate of cast iron which is often let into the ground alongside of the anvil stand for this purpose. Another way is to lay the bar in a horizontal

position upon the anvil face (Fig. 79), holding it in one hand if light, and, with a hand hammer, hammering the end to be upset. Or, if it is heavy, it may be held in both hands, or, perhaps, slung in a chain from the forge crane, and upset with a sledge hammer. When very heavy, it is laid upon the anvil face or upon a leveling block, and the swinging monkey is driven against it.

Three or four heats are often required to jump up a moderate mass of metal. The result is, that fairly exact dimensions are not at once obtainable by this method, as in the case of drawing down. The jumped-up mass of metal, in spite of much care in localizing the heat precisely where it is required, is very unequal, and quite without sharp shoulders. Hence, considerably more metal has to be massed together than is actually required in the completed work, in order to allow of symmetrical finish to size. Upsetting tends to separate the fibers of the metal. It is, therefore, necessary to counteract this by hammering the jumped-up portion at a welding heat. When the metal for the collar is massed in sufficient quantity, it is finished parallel in swages, and the square shoulder finished with a set hammer or flatter, or in swages, and the end with hammer and flatter.

A collar can be also formed upon any portion of a bar situated away from the ends by localizing the heat in the position required, and then jumping up the metal at that particular place, until sufficient mass is obtained for finishing to size and shape. Any other sections can be heated, and the spreading out can be performed by upsetting in one direction more than in others.

CHAPTER IV.

WELDING AND PUNCHING.

Weldability is one of the most valuable properties possessed by wrought iron and mild steel. Welding is often the alternative of drawing down or of upsetting; correct heat and cleanliness are the chief requisites. Welding heat corresponds with that temperature at which the metal is in a state of partial fusion on the surface. At that temperature it is extremely plastic, and a little hammering will cause two surfaces to adhere and possess as much strength as the other parts of the metal. The welding heats for iron and steel differ, and even also the heat for different qualities of iron and different qualities of steel. Any iron will require a much greater heat than steel, and the better the quality of iron, the higher the welding heat that it will stand without becoming burned. At a welding heat iron gives off dazzling sparks; steel shows only an intense yellow, and gives off few sparks. The ascertaining of the correct heat is a matter for experience entirely, and no description or illustration can take the place of practical lessons.

To illustrate the process of welding more clearly, two plain examples, one a collared rod, and the other a plain straight rod, are given.

Taking the shouldered end (Fig. 80), first cut off the rod, A, and then prepare to fit over it the ring, B, for which take a square bar, say ⅛ in. larger than the finished section required, and, with a hot set, cut off one end diagonally or else fuller it down. Then bend the bar roughly into circular form over

the anvil horn (Fig. 81), and cut off to the required length, with a sloping face to lap upon and match the first diagonal. The metal must have sufficient lap to allow for welding, and for dressing off and finish-

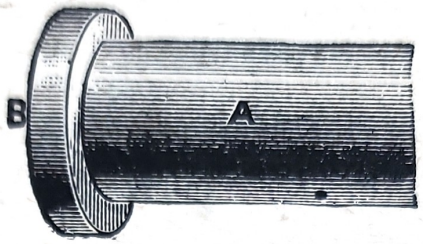

Fig. 80.—Bar with Shouldered End.

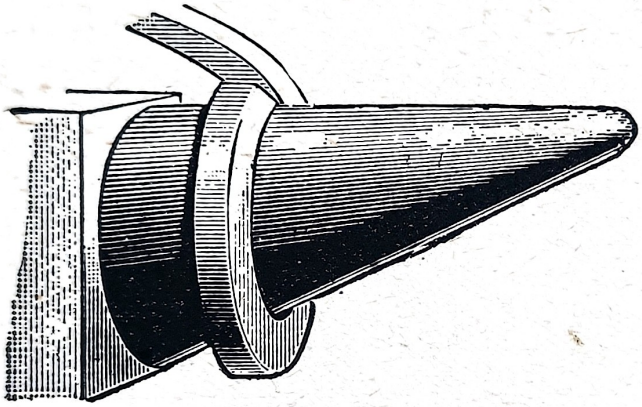

Fig. 81.—Forming Ring on Anvil Beak.

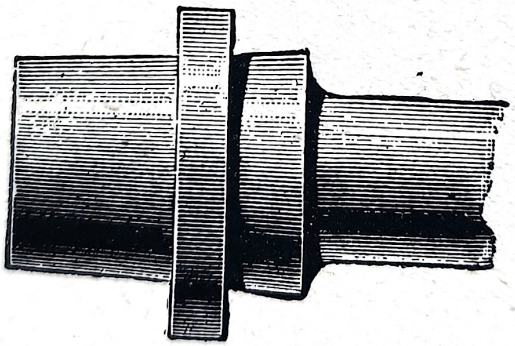

Fig. 82.—Ring slipped over Mandril.

ing. If the ring is fairly true, it will be ready to go into the fire for welding; but if not, slip it over a mandrel, Fig. 82, and give the scarfed joint a neat appearance, either with the hammer alone or with one of the hollow tools previously described. Then

slip off the ring and flatten the faces (Fig. 83). This is precisely the plan that would be adopted in welding a separate ring.

To weld it to the rod, the ring is slipped over the end of the rod, care being taken to remove any scale adherent to either, and they are then put into the clear fire. Sand may be sprinkled over the work, but with a clear fire it is not necessary, and is frequently not done. When the welding heat is attained, which for wrought iron is of a dazzling whiteness, when the iron seems ready to melt, and particles appear ready to drop off, and a rapid evolution of sparks takes place, the work is removed from the fire, placed on a V-block (B, Fig. 62), and the scarf joint and the ring are hammered all round with a

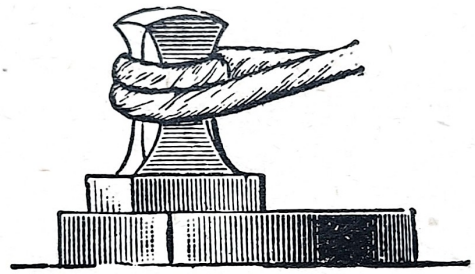

Fig. 83.—Smoothing Faces of Ring with Flatter.

hand hammer, the rod with its ring being continually turned into fresh positions on the V-block. If a hammerman's services are available, the hollow tool is used, and a few blows upon it consolidate and smooth the surfaces. Then the faces and shoulders are finished by means of a heading tool, having a hole of a size suitable to take the rod, a few blows with hammer and flatter finishing off both the under shouldered face and the upper flat face. Then it may be necessary to work over the circular part again with the hollow tool. This is to finish the surface, for the welding heat is soon past, and if the union of the joint faces is not fully effected in the first few seconds, it will be more or less imperfect.

To weld a rod, a scarfed joint is employed, and plenty of metal is wanted to allow for hammering the joint together and for finishing it afterwards without reducing below correct sizes; therefore, the ends of the bar have not only to be scarfed, but to be slightly upset. The meeting ends, which have been cut off square, are laid horizontally upon the anvil, and are upset or beaten over, while nearly at a welding heat. Then they are laid over the edge of the anvil, and scarfed or beaten down diagonally with a fullering tool, the face of the scarf being made rounding rather than hollow. Both ends having been served precisely alike, they are put back into the fire, and raised to the welding heat. Lift the

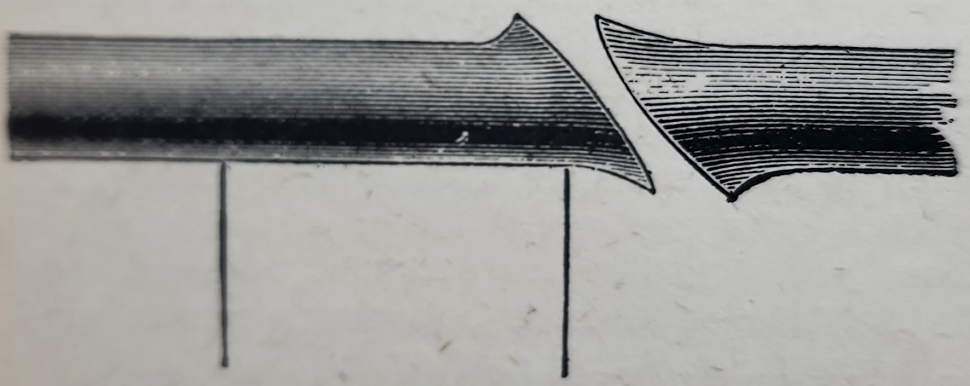

Fig. 84.—Ends Scarfed and Upset ready for Welding.

work vertically out from the fire; do not drag it through the coal. Any particles of dirt that are present will show as dark specks on the white-hot iron, and should be brushed off with a switch of brushwood.

The smith and his helper lay the scarfed ends together, as shown in Fig. 84, and then two or three blows with the hand hammer cause the ends to unite, and the rod can then be rapidly turned about on the anvil while the joint is consolidated all round with hand hammers or sledges. The top and bottom swages can be used for imparting the finish required. It will be apparent that without the first

enlargement or upsetting of the rods, the process of welding and swaging would have thinned the rod at the welded section below that of the other portions. How much to upset and how much to scarf are matters for experience.

These notes on welding are somewhat of an elementary character, but further information on the subject will be embodied in the descriptions of working miscellaneous examples.

Punching, drifting, and drilling are the three methods by which the smith commonly makes holes in metal. The first two are performed on red-hot iron and steel; the last, and sometimes the second also, on cold metal. Drifts, and the method of using them, are dealt with in the chapter on hand tools (see pp. 20 to 40), and at present punching alone will be treated upon.

Punches may be used to make a clean, finished hole, to which nothing is done subsequently, and which is quite good enough for its purpose. In other cases, punching, like the coring of castings, takes out the bulk of the metal, leaving a certain small allowance for finishing with drill, reamer or boring tool.

Generally the details of the process of punching are as follows: The iron to be punched, being brought to a suitable heat, full red or white, is laid across the anvil, and the punch is driven by means of blows from a sledge or hand hammer, about halfway through. The punch is then withdrawn, and the iron is turned over and laid upon its opposite face. A dark spot indicates where the chilling effect of the punch has taken place, and enables the smith to set the punch again in position for piercing the metal so that the holes meet. During the formation of the second portion, the work is either laid upon a bolster or over the hole in the anvil, and the punch then passes freely through.

If the hole is deep, the hot iron closes and tightens around the punch, and the latter is therefore withdrawn at every three or four blows. Further, the heat of the iron makes the punch very hot, so that after every three or six blows it is necessary to cool the punch in water.

Methods of producing punched holes vary according to circumstances. If it is desired to preserve the same amount of metal all around, the hole is partly punched and partly drilled or opened out. Obviously, when a hole is punched entirely with a flat-ended tool like Fig. 65, p. 36, the metal removed is equal in area to the area of the point of the punch itself, and the width of the bar is only very slightly perceptibly increased (see Fig. 85).

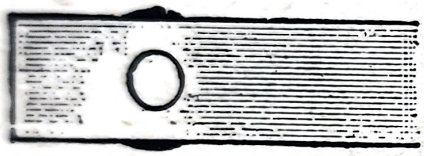

Fig. 85.—Material removed by Flat-ended Punch.

Fig. 86.—Commencing Hole with Hot Set.

Another way of making a hole without weakening the bar to any great extent is by means of a conical punch, which may be inserted, and the hole formed and opened, without the removal of any appreciable quantity of material. Or if a hot set is driven from one side half-way through the bar, and half-way from the other (Fig. 86), a punch or drift can be driven in afterwards, and the slit opened out into circular or oblong form, as may be required.

Long slot-holes are cut in two ways. In one, holes are punched at each end of the intended slot equal to its width, and the metal between is cut out with the hot set, cutting from opposite sides in succession, and meeting in the middle (Fig. 87). In the other, holes are punched at each end, and a chisel cut made centrally from hole to hole, and a drift

inserted and the metal opened out (Figs. 88 and 89). In this way the flanking metal is thrust out sideways, and the bulk of its section retained. Such a slot-hole is finished by inserting a drift or mandrel of the correct section, and hammering the outside edges of the bar upon it.

When punching holes, it is necessary to take account of the direction of the fiber. Unless attention is given to this, the iron will become divided instead of spread out. Punching puts considerable tension on the fibers around the hole, with reduction of area, and it is an operation, therefore, that requires to be done with judgment.

Fig. 87.—Slotted Hole; Area Reduced.

Figs. 88 and 89.—Slotted Holes; Area Retained.

To punch slotted cottar ways in which the section of the iron is not enlarged, take a tapered oblong punch or drift of steel, like that shown at A, Fig. 90, with rounding ends. Raise the iron to a welding heat, and properly support it according to its shape, upon a bolster or a bottom tool, and drive the punch half-way into it. Turn the iron over, cool the punch in water, and drive it in exactly opposite to the first position, until the openings meet at the center of the bar. The slightly tapered punch makes a hole doubly tapered, which is also rough. A parallel drift or filling-piece is then driven into the hole,

which accommodates itself to the form of the filling-piece. The outside of the iron is smoothed and finished, and when the shape is completed the filling-piece is driven out. This method of finishing a job while a central punch, drift, filling-in piece, or mandrel remains in the work, is adopted in many classes of work.

Punching a hole through a stout pin is illustrated

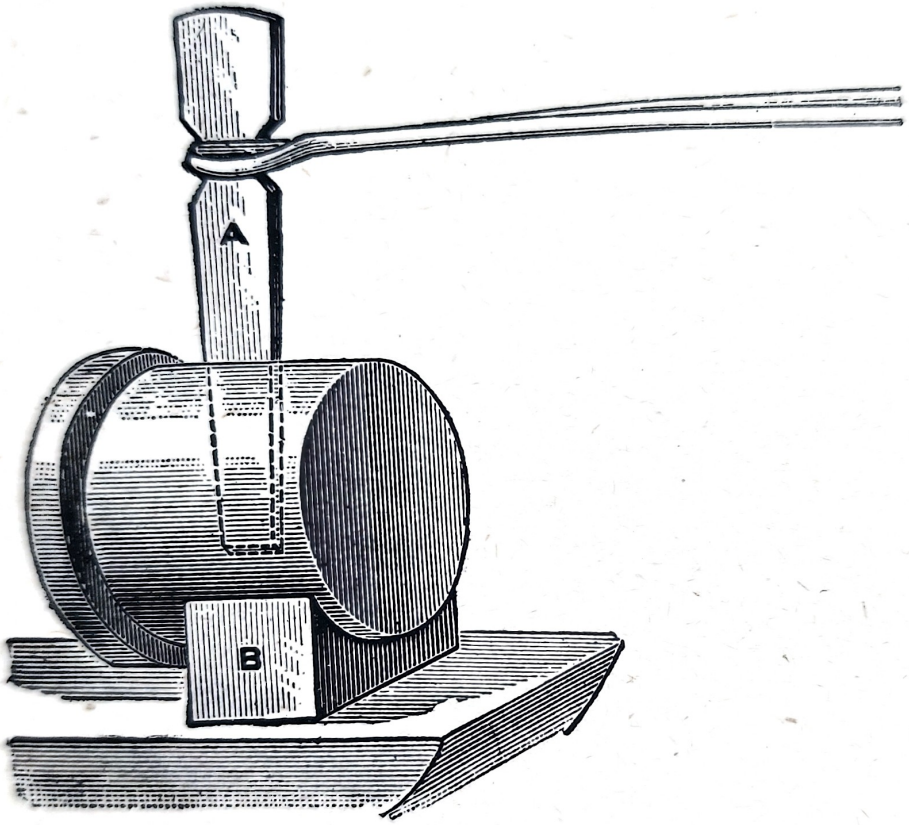

Fig. 90.—Punching a Hole through a Stout Pin.

by Fig. 90, the pin selected being 3¼ in. diameter; the hole measures 1½ in. by ½ in., and is made at one heat. The punch, as shown, has its body below the handle, about 6 in. long, and is tapered. The pin being brought to a white heat, the punch is driven almost through. Then the pin is turned over and the punch driven into the darker spot which has appeared, and the hole is thus completed. During the punching the tool has to be several times cooled

in water. At the first stage of making the hole, the pin lies upon an ordinary bottom swage. At the second stage it lies upon a bolster, B, in form like a hollow swage, but pierced with a central hole, through which the drift can find a clear way.

As the hole is thus roughly punched, the metal around it will be partly compressed, partly bulged; very little is actually driven out and removed by the punch. The bulging of the pin is corrected by hammering between top and bottom swages, and then the hole is finished by drifting, all being done during the one heat. During the punching, whenever the punch is withdrawn to be cooled, a little small coal is strewn in the punched hole, to burn up the gas which would otherwise resist the passage of the punch.

CHAPTER V.

CONDITIONS OF WORK; PRINCIPLES OF FORMATION.

The smith works under three conditions, each of which ought to receive separate treatment. These are: first, when he works alone, without the assistance of a striker, or of steam power, or of dies; second, when he has the assistance of a striker or hammerman, but is still without steam power; third, when he has the help of a hammerman, and has also the use of a steam hammer, and dies of various kinds. Amateurs and many country and jobbing smiths come under the first category. Men in small workshops come under the second; whilst the third class embraces the men in large engineering and general iron works.

It is obvious that the particular circumstances under which work has to be performed must often modify the methods adopted. For example, a smith who has the use of a steam hammer will either swage or draw down, when such is practicable, in preference to upsetting and welding. Again, a smith who has command of dies and steam hammer will not spend so much time in finishing and smoothing the surfaces, angles, and corners of his work upon the anvil, because he can put his roughed work between a pair of dies, and finish it with a few blows of the steam hammer. The smith who has no help from a striker will be restricted to the very lightest work. Iron of nearly the finished sizes and sections wanted will have to be used. Extensive drawing down and welding cannot be done; little is possible beyond work that can be done with the

hand hammer. Swages, flatters, fullers, and chisels—except the anvil cutters—are of scarcely any use when there is available only one pair of hands for holding the work and the tools.

The class of work that comes within the range of the unassisted smith differs from that of the worker who is favored in the matter of assistance and tools. But he has still all the wealth of ornamental work, like that done by mediæval smiths, all tool work—almost anything, in fact, where the sections of iron and steel do not exceed, say, 1 in. to 1¼ in. in diameter. Obviously, the choice of forges, tools, as well as methods of work, will be different under these several conditions.

In the judicious choice of that which is the best out of several possible methods, lies much of the skill of the experienced smith. It by no means follows that a method by which a piece of work can be forged to shape is necessarily the quickest, cheapest, or best; or that which may be the best method under certain conditions is the best in all or any circumstances. One often has to adopt a method which may not be best from another's point of view, because he either does not possess the iron of proper sections, or the special tools, or other necessary assistance. This fact is made more forcible when the numerous sections of iron required by the all-round smith are considered. Even in large shops, where steam hammers are available, it is often impossible to manipulate the heavier sections of iron. These require very powerful hammers, in order that the force of their blows shall penetrate to the interior of the mass. Hence many engineers find it necessary to order for massive work specially heavy forgings, or "uses," as they are called at the rolling-mills.

The material of a single-handed smith, and that of an amateur, is limited to small sections. With a small forge no great heat is possible, and a smith

working single-handed cannot manipulate any heavy sections. Bars of iron are made in lengths of several feet, and the purchasing of a fair stock of entire bars of several sizes would prove a heavy expense. It is best to select a few bars of the most useful dimensions, according to the class of work which it is intended chiefly to do, and when any other sections happen to be wanted, to purchase them in short lengths from a local smith or at an iron store.

The principal shapes of iron used by the smith are "round," "square," and "flat" bars. These are made in almost all ordinary dimensions, and in different qualities. The published lists of sections rolled at some of the best-known iron and steel works in this country are here made use of.

The bars are rolled in the following Wire Gauge sizes: 7, 6, 5, 4, 3, 2, 1; and also ranging from 3-16 in. up to 2⅝ in., increasing by sixteenths; from 2⅝ in. to 5 in., increasing by eighths; from 5 in. to 5½ in. by quarters; from 5½ in. to 6 in. by eighths; and from 6 in. to 6½ in. by quarters; and each of these can be rolled to "full," and "bare," as well as to exact sizes. Thus there are obtainable sixty-eight different diameters of round bar, from 3-16 in. to 6½ in.

The squares increase from 3-16 in. to 1⅝ in. by sixteenths; from 1⅝ in. to 4 in. by eighths; from 4 in. to 5½ in. by quarters; and from 5½ in. to 6½ in. by half-inches; giving fifty-one sizes in square sections from 3-16 in. to 6½ in.

The flats range from ⅜ in. to 12 in. wide, in almost all thicknesses from ¼ in. upwards, advancing by sixteenths and eighths. Flats in sixty-five different widths are obtainable.

This iron is made in four qualities—the "ordinary," or common, "best," "best, best," and "best, best, best."

Good metal being rather costly, a careful smith

will preserve odds and ends of iron and steel for small work, and for welding to other portions, so saving the cutting off of small pieces from long bars.

It is not economical to buy inferior iron. The quantities used in light work are so small that the saving is scarcely worth taking account of, while inferior iron is a constant source of anxiety to the smith.

The differences in the qualities of iron are broadly these: A good iron is silvery and clean-looking; a bad iron is dull and dirty by comparison. A good iron is free or nearly free from flaws, which in a bad iron always show up when it is brought to a red heat. They are due to the intermixed cinder and scale left by insufficient puddling. The way to get rid of some of these is to subject the iron to a welding heat, and hammer it thoroughly all over to consolidate it in some degree.

Carbon, manganese, phosphorus, and silicon exercise so vital an influence upon the numerous alloys of iron and copper as in many cases to totally and absolutely change its appearance and physical qualities. But in wrought iron, where the foreign ingredients seldom amount to more than 1 per cent, being often only ½ per cent, those very minute admixtures are found to affect the metal to an extent that makes itself very evident at the anvil. The most readily forged, whether hot or cold, is that which is the purest. Iron that will forge well while hot, but not when cold, is said to be "cold short," and this is due to very minute quantities of phosphorus, antimony, and silicon. When iron is apt to develop cracks while being forged hot, it is said to be "hot short," and this may be due to a minute quantity of sulphur, whose amount may not perhaps exceed .03 per cent, or it may be due to antimony. Only delicate chemical analysis could demonstrate the presence of these

foreign elements, but the smith sees their results when the iron is under the hammer and punch.

The most striking characteristic of wrought iron that has been rolled is its fibrous condition, and this occurs also, in a lesser degree, in mild steel. This is the quality by which it can be shaped according to the will of the smith. It is a remarkable property of these fibrous materials that the very qualification that is of so much value can be changed or modified in the working. A bar of iron placed across the anvil cutter and nicked around with a chisel, may be broken off short with little effort, and a practiced eye is necessary to detect whether the iron is cast or wrought by the appearance of the fracture, which is wholly crystalline. The same bar bent without nicking, or gradually torn asunder until it breaks, shows the fracture wholly fibrous, the long, string-like fibers becoming drawn out as though the bar had been built up of innumerable fine strings of metal. Again, if a crank-shaft or a lever-arm breaks at a sharp re-entrant angle, the fracture will be crystalline. But if it breaks at an angle whose faces are gradually merged into one another with a curve or hollow, the fracture will be fibrous.

It follows from the fibrous character of wrought iron developed during rolling, that it must be considerably stronger in the direction in which it is rolled (A, A, Fig. 91) than in the transverse direction, B, B. The difference is in about the ratio of 21 to 17—that is, if it would require 21 tons per inch to break the bar through the line B, B, in a direction at right angles with A, A—that is, across the fibers—17 tons would suffice to break it along A, A—that is, along or with the fibers. This holds good to a very slight extent only in mild steel, where the rolling is only incidental to the shaping. The direction and relative strength of fiber have a most marked influence upon design in wrought iron. It shows why the

direction in which work is subjected to the greater stress should always coincide with the longitudinal direction of the fibers; why curved work should not be cut from the solid, thereby severing the continuity of the grain, if it is possible to bend it round and so preserve the fibers continuous. It shows why in many cases it is better to split or divide a bar, and bend or fork it, so preserving continuity of grain, rather than to slot out or to weld on. It explains many practical points in the working of wrought iron as distinguished from the working of the homogeneous mild steels. It shows the advantage of keeping

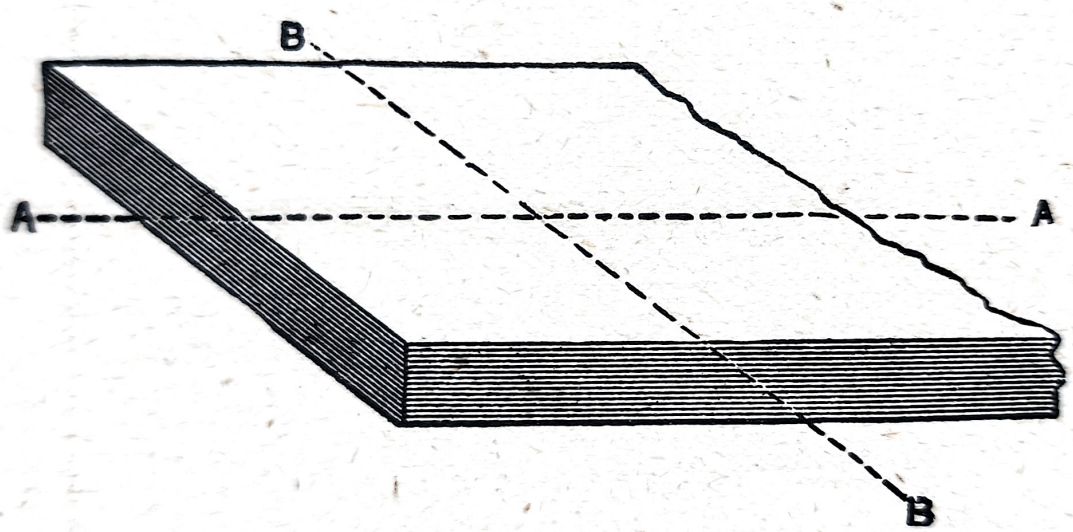

Fig. 91.—Direction of Fibre in Iron Bar.

the edges rounding and not sharp on fullering and similar tools, by whose use the grain is not violently severed, but rather bent to shape.

The action of the fuller is typical forging, for it reduces the surface of the work without leaving angular marks upon its surface. It does not cut at all, but leaves a wavy surface, with fiber perfectly continuous. When making a set off in a bar, whether with the object of reducing its dimensions or of bending it, the round-faced fuller is the tool that is used —never the keen chisel. The edge of the set hammer is also usually a little rounding, and does not

form a sharp angle. The same applies also to most of the swages and other tools employed in working out forged forms.

The following figures illustrate in detail these remarks: The crank, Fig. 92, is forged as a solid block, and slotted out at c, whilst the one shown in Fig. 93 is bent round or dipped. When the crank (Fig. 92) is slotted out, the crank webs, *a*, *a*, are weak, because the grain or fiber runs in the direction of the engraved lines, and the condition is quite

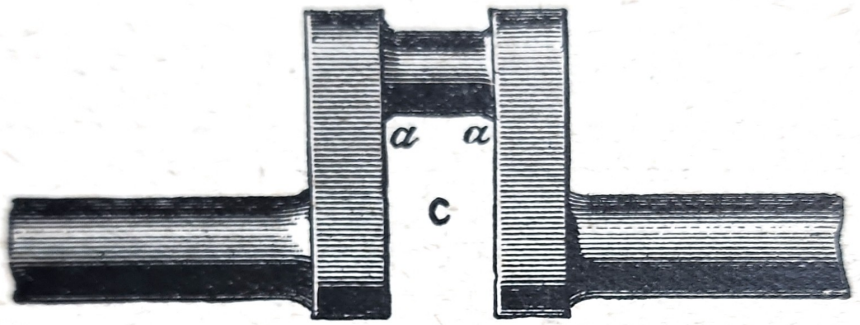

Fig. 92.—Slotted Crank.

Fig. 93.—Bent Crank.

analogous to the short grain in wood. In Fig. 93 the fiber follows the contour of the dip of the crank, and therefore the crank is of equal sectional strength throughout. The weakness of the form, Fig. 92, is shown very forcibly in locomotive practice. The cranks of inside cylinder engines are made in this manner, and unavoidably so, because there is not room enough to use a bent crank like Fig. 93; these cranks invariably fracture at one of the webs (*a*) when the engine has had a total run of about 200,000

miles. Frequently the webs break before that limit is reached, and for this reason the practice of bonding is now often resorted to. The crane lifting-hook, Fig. 94, is invariably bent round like the dip crank, and its sectional strength is preserved. If it were slotted the hook would break with much less strain.

Instead of drilling a hole for the eye, *b*, of this crane-hook, it should be bent round and welded, or else punched. In drilling, the metal is severed; in

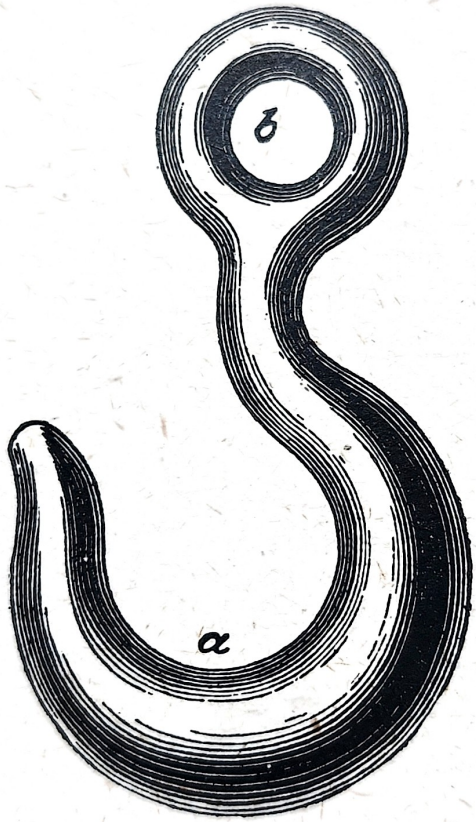

Fig. 94.—Crane Lifting-hook.

punching, it is thrust aside and not divided. The punching preserves the continuity of the fibers, and, by bulging out the metal upon each side, preserves an equal section, and little or no jumping up is required. The punched rod (Fig. 95) is an illustration of the same kind occurring in the middle of a bar, and is common in roof trusses.

The eyes of hammers, and the cottar ways in bolts and rods, should always be punched. There is

then no separation, but only a parting or spreading of the fibers.

In forging the eye of a winch handle (Fig. 96), instead of making a solid end and drilling and filing a square hole, the bar is bent round a mandrel and then welded.

Figs. 97, 98 and 99 show how the continuity of fiber is preserved in large forked ends. Small ends

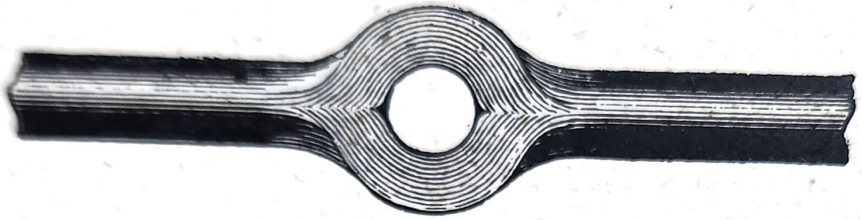

Fig. 95.—Punched Tie Rod.

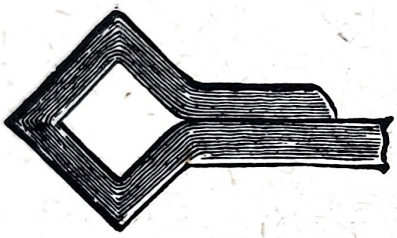

Fig. 96.—Welded Eye.

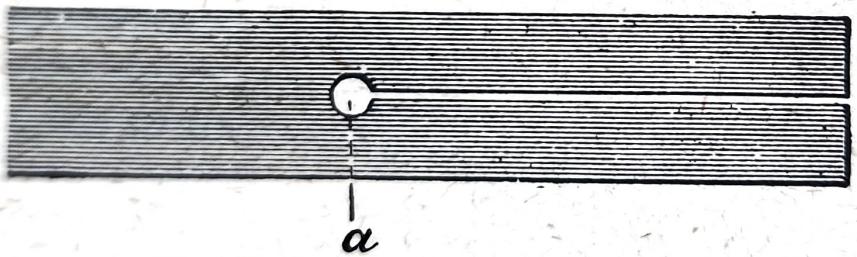

Fig. 97.—Bar divided with Hot Set.

are usually shaped out of the solid but broad ends, like that illustrated, and also those of moderate width are formed by dividing the bar and then opening it out. Fig. 97 shows the bar from which the forked end has to be made. A hole is punched through at *a*; this does not sever the fiber, but merely thrusts it sideways. Then the bar is divided with a hot set from the hole *a* outward to the end.

The set is driven first from one face half-way through the bar, and then from the other face to meet in the middle. The punched hole prevents all risk of

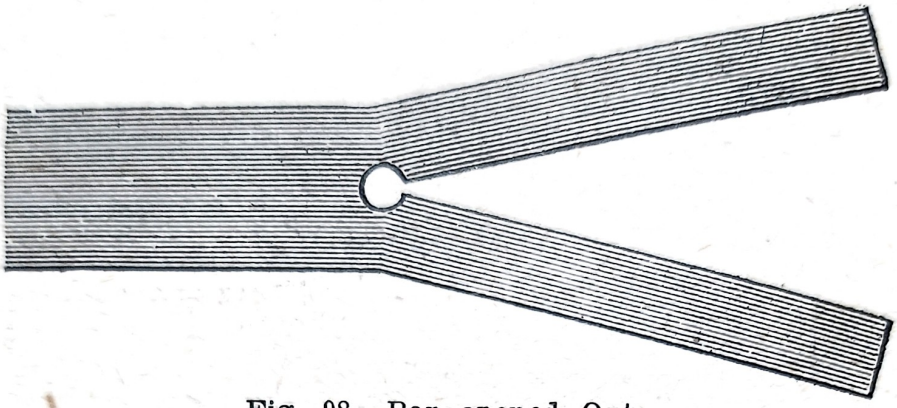

Fig. 98.—Bar opened Out.

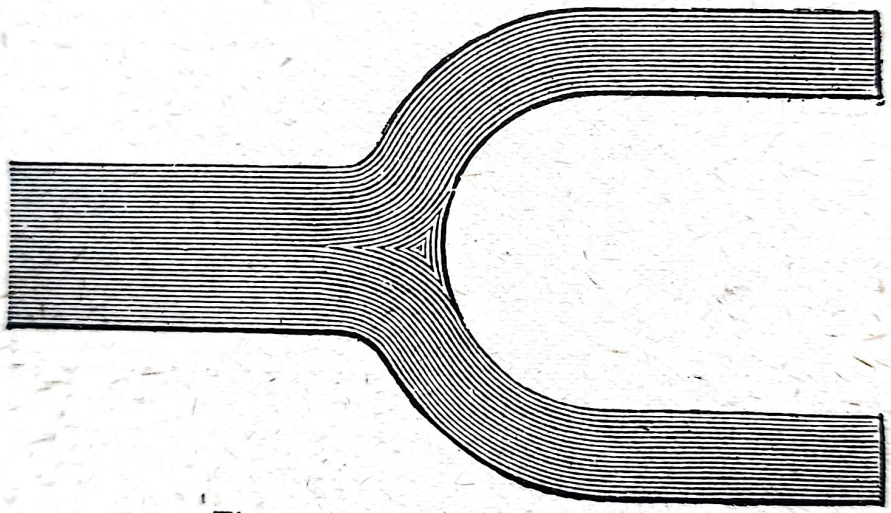

Fig. 99.—Finished Fork End.

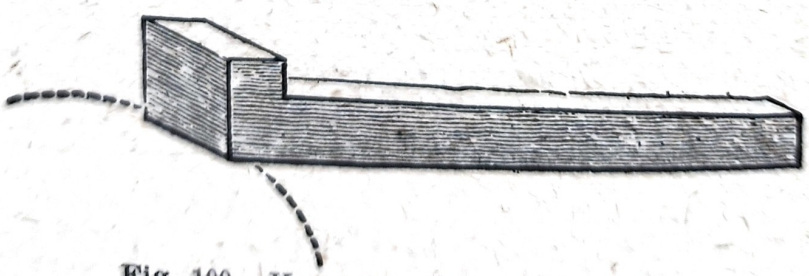

Fig. 100.—Key with Fiber Incorrect.

the set splitting the fibers inwards beyond the hole. Then the bar is opened out, first with a wedge, afterwards with the hammer, as in Fig. 98, and

finally finished as at Fig. 99. If the fork were cut from the solid, the fiber would be short; but being opened out and bent round, it runs continuously.

The direction in which the layers of iron occur has frequently to be considered when making forgings. In a cottar key, for example, the layers of iron should be arranged, not in the direction of rota-

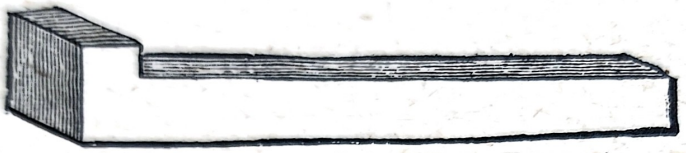

Fig. 101.—Key with Fiber Correct.

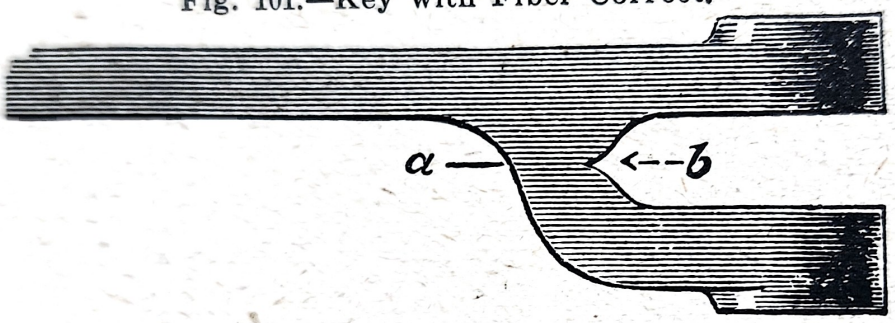

Fig. 102.—Forked End with Fiber Incorrect.

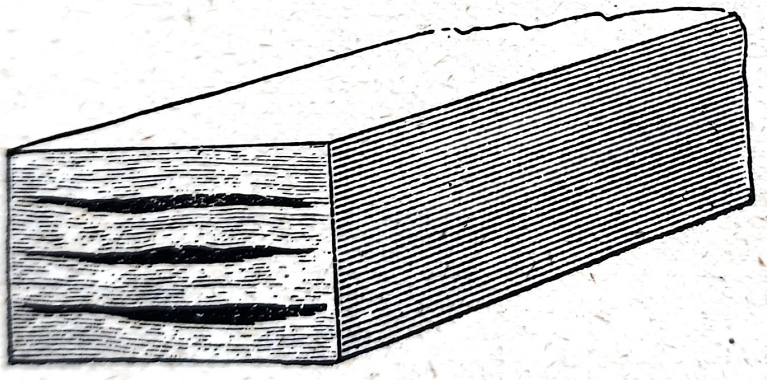

Fig. 103.—Cracks in Bad Iron.

tion of the shaft as in Fig. 100, as the pressure would tend to shear the key off in the plane of the layers, but at right angles, as in Fig. 101, that is, the layers should radiate the center of the shaft, so that the pressure will tend to close them. Nuts should be punched at right angles to the direction of the fiber, otherwise the layers of iron are liable to become separated. The forked eccentric rod end (Fig. 102),

forged solid and slotted out, should have the layers run not as engraved, but in the plane of the paper instead, otherwise the fiber is apt to open at *b*, and the forked end may fracture along *a*, *b*.

Liability to crack is much greater in inferior iron than in that of first-class quality. It is not unusual when cut off with the hot set to find the bad qualities of iron showing cracks at the end (Fig. 103). These cracks are due to imperfect union, and to the presence of cinder, which has become intermixed with the iron and not expelled during the process of shingling. Sometimes hammering at a welding heat will improve such iron, but if the composition of the iron is bad, there is little advantage to be gained by this.

Anything that has to be screwed or subjected to great stress or wear, should be forged as sound and close-grained as possible by consolidation under the hammer, or between top and bottom tools at a welding heat. Otherwise the fibers may become partly separated and the metal frayed, so that the open texture of the iron will collect grit and wear rapidly.

CHAPTER VI.

BENDING AND RING MAKING.

This chapter will deal with some of the various methods employed in bending iron and in forming rings in that metal. Curves and rings of light section are easily bent over the beak of the anvil, or around a mandrel of suitable diameter. When the sections are heavy, bending blocks are necessary. It is easier to bend bar-iron flatwise than edgewise; the reason is apparent if it is remembered that when a wide bar is bent two things happen. Along the center of the bar (A, A, Fig. 104) there will be a neutral axis of metal

Fig. 104.—Diagram to Illustrate Tension and Compression.

that bends without compression or extension of fiber. But outside this neutral axis, the metal, B, B, is extended, and inside of this axis the metal, C, C, is compressed. The metal in tension and the metal in compression will seek relief from the intense stresses to which it is subjected. It will become wrinkled and puckered upwards and downwards. This tendency has to be corrected by hammering, or by the use of mechanical devices.

Many devices are resorted to in bending work of various sections and outlines. The making of a special cast iron templet, or bending block, is a question of relative cost. Where only a few plain pieces have to be bent, it will not pay to make the simplest block.

Where there are many pieces, all alike, it pays to cast most elaborate blocks, and to fit them up with clips and cottars, or whatever may be necessary besides. It is usually easy for the smith to design blocks for forgings which he may require.

Fig. 105 shows a common type of block used for

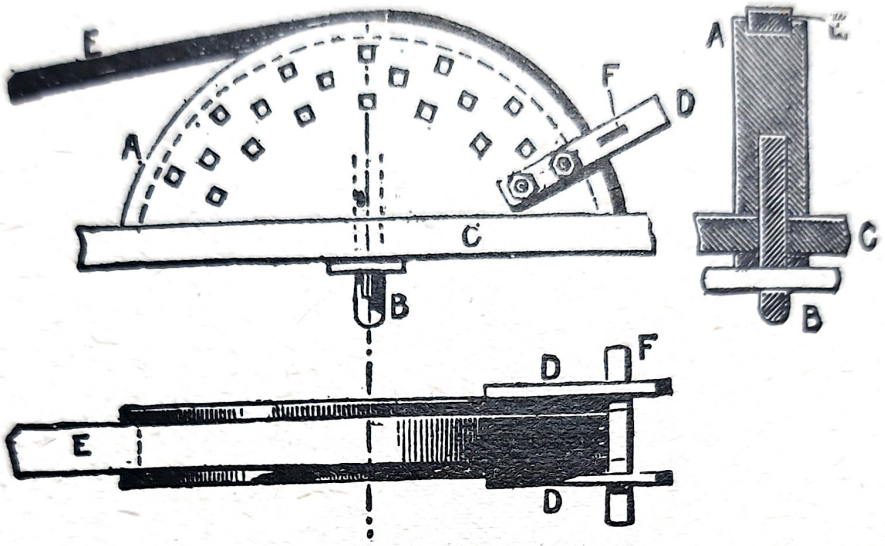

Fig. 105.—Bending Block.

bending flat bars. Made in suitable sections, it is also often employed for bending T-iron. As shown, the working edge, A, is a circular arc; but it could be shaped to other curves equally well. The block has cast in it a stout cottared pin, projecting from its bottom face. This pin passes through a suitable hole in the levelling block, C, and is cottared beneath. For holding down cast-iron templet blocks, this is the most convenient method—better than having movable clips. One end, E, of the bar to be bent, is confined in its groove by clips, D, D. They are fastened with bolts through some of the holes, many of which are usually cast in all bending blocks, the cottar, F, passing through slot holes in D, D, holds the bar, E, down in its groove. As the free end of the bar, E, is bent farther round, more clips are brought to bear upon it, otherwise the bar could rise up from its seating.

Fig. 106 shows a common levelling and bending block fitted with a screw for general work. Upon it bars and plates of metal can be straightened and levelled by hammering. Forgings in process of formation can be tested from its face by the try-square, the back of it being laid upon the block and the blade

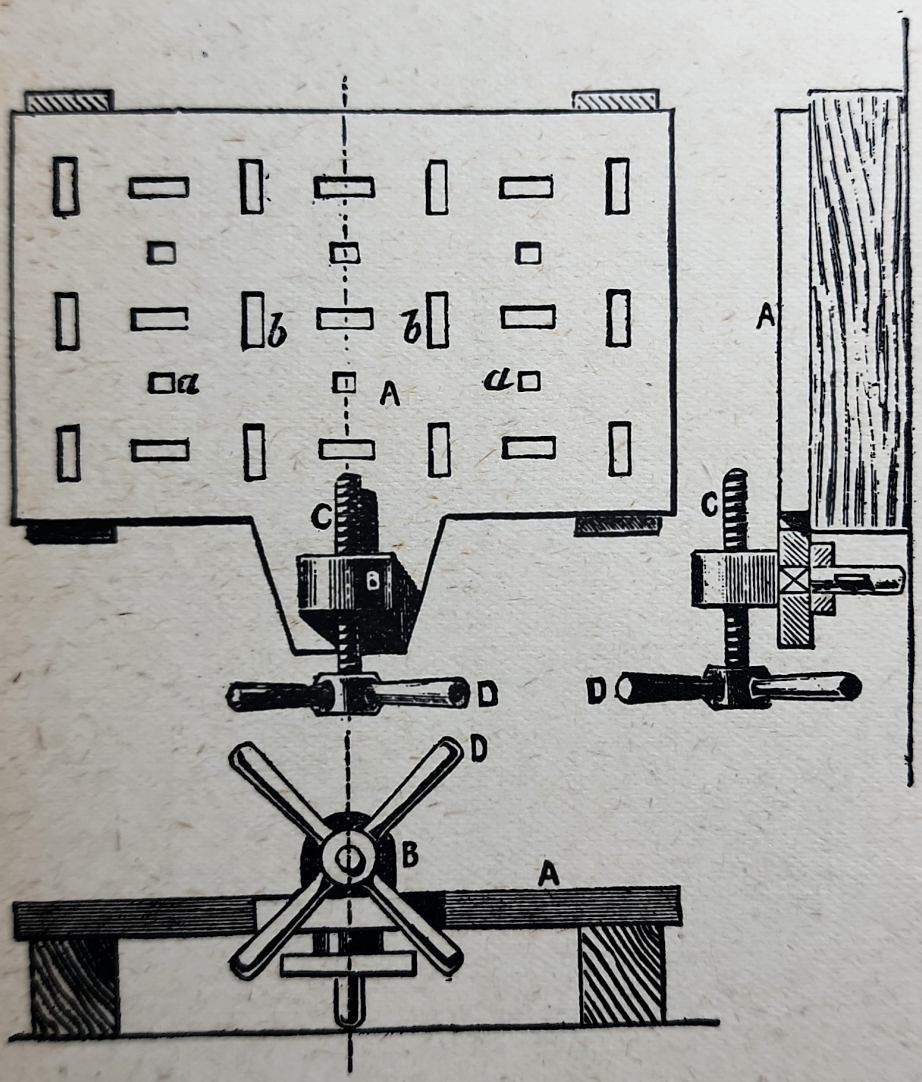

Fig. 106.—Levelling Block with Screw.

against the vertical face of the work to be squared. The bevel gauge can be similarly used. Work can also be taken out of winding upon its surface; and it is used largely for bending iron bars to various curves. The block, A, is pierced with numerous cir-

cular and slotted holes, which receive pins forming the necessary supports for leverage when bending. There should be plenty of holes, but the plate should not be unduly weakened. At B there is a screwed

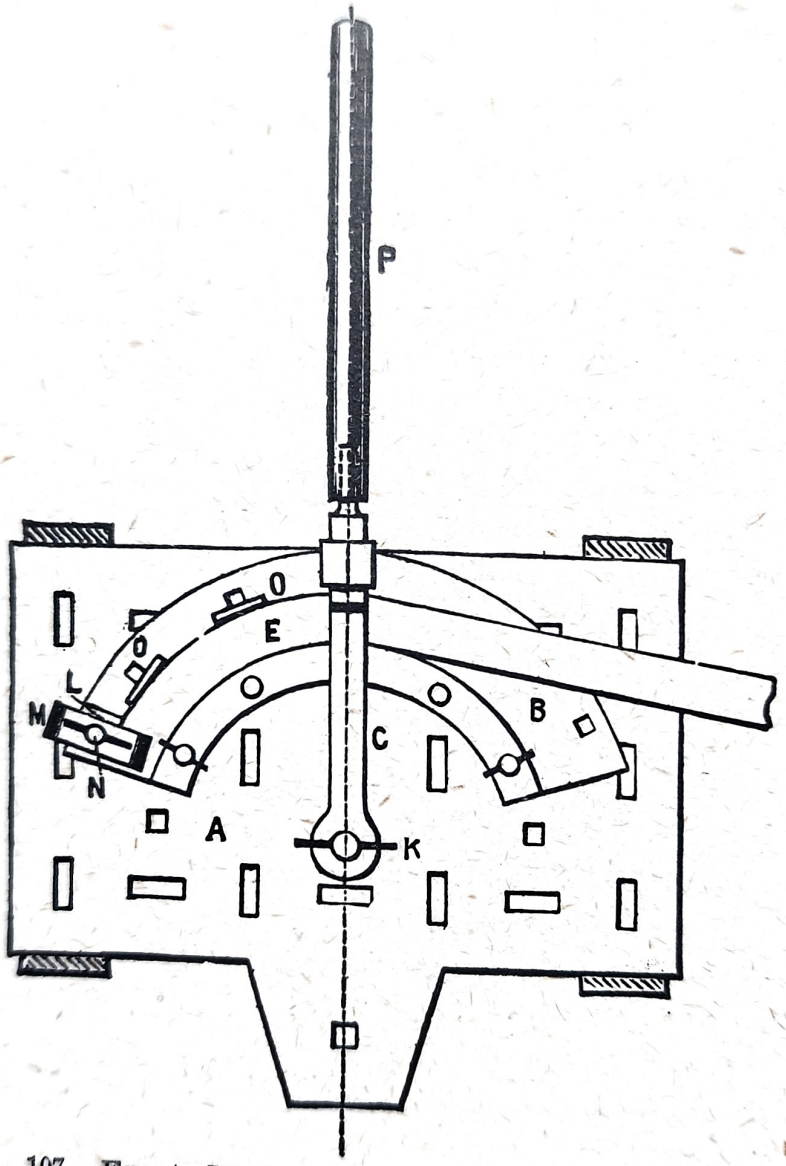

Fig. 107.—Front View of Levelling Block with Bending Templet.

block, secured to the plate with a shank or pin through which a cottar way passes. Driving in the cottar underneath secures this block in position, and by the interposition or removal of a ring the height

of the block can be varied. Through the block passes the powerful square-threaded screw, C, which is operated by the heavy cross handle, D. It is evident that if pins be inserted in holes, say at *a*, *a*, or at *b*, *b*, they will afford points of resistance to a bar that is laid against them when pressure is brought to bear about its central portions by the screw, C. As the ends of the bar cannot yield, it will be bent. By shifting the pins into other holes, the curvature of the bar can be varied.

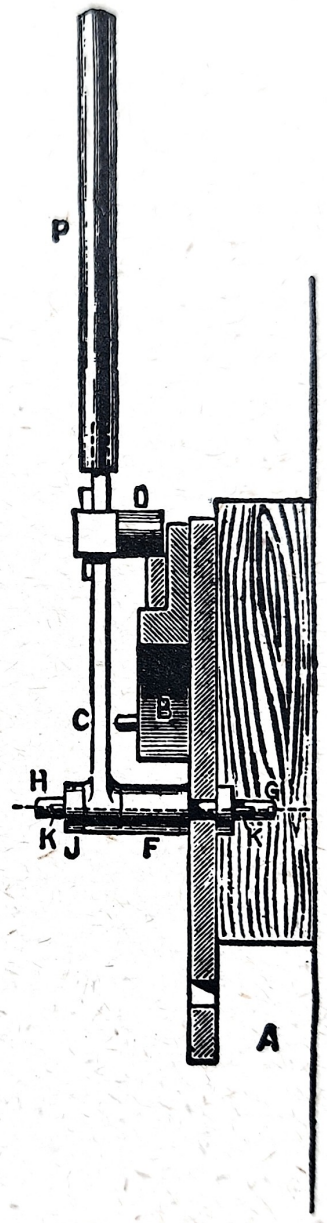

Fig. 108.—Side View of Levelling Block with Bending Templet.

Figs. 107 and 108 illustrate another method of making a ring upon the bending block, shown in Fig. 106. A is the block; B is a templet casting, cottared down to the levelling block through the rough holes cast in the templet, the pins passing through any of the holes cast in the bending block that happen to be conveniently situated. The block is set so that its curvature follows round some particular hole in the bending block, in order that the radius bar or lever C, with its roller, D, may operate with equal pressure upon the ring, E, in every position. The lever moves upon a substantial pivot, F, whose shank or pin passes through the plate, and is cottared below. The detail of this fitting is shown in Fig. 109, where F is the solid body of the shank,

whose pin, G, passes through the bending block, A. H is the pin upon which the bar, C, pivots, and J is a collar, of which one or more may be used for adjusting the height. K, K are top and bottom cottars.

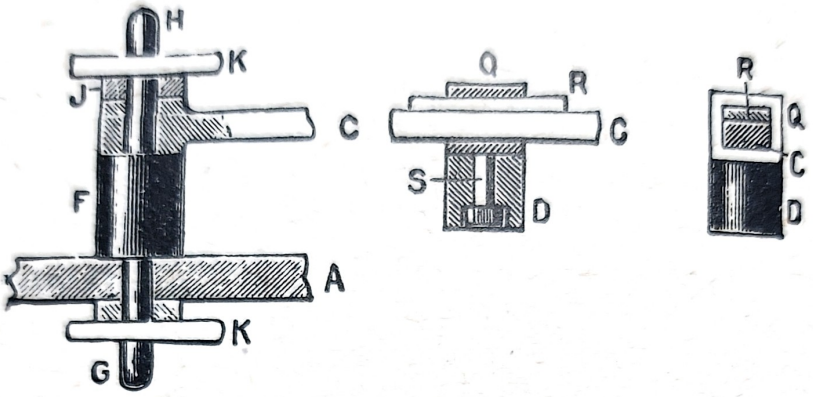

Fig. 109.—Details of Lever.

One end of the bar, E (Figs. 107 and 108), to be bent is heated, and then secured at one end of the curved templet. As these templets are made specially to suit each job, and not for general work, it is usually practicable to cast a stop at the end where the bar is first secured. Such a stop is shown at L, Figs. 107 and 108, and in detail at Fig. 110.

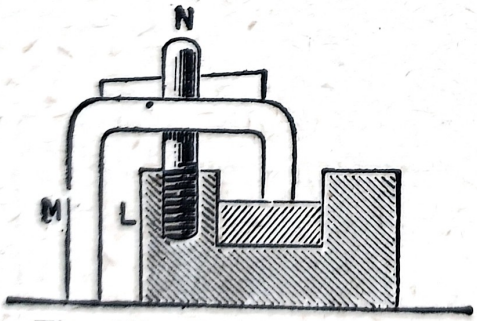

Fig. 110.—Details of Clip.

Fig. 111.—Reversing-link.

This particular templet represents one used for making rings from which to cut the reversing links, of the type shown in Fig. 111, of the motion work of engines. Where such links are made in quantities, this is a cheaper method than forging and filing or machining each link separately. Making a ring with

radius equal to the curvature of the link, it is turned all over in the lathe, and then the separate links are slotted out of this ring, all being exactly alike.

In such a case as this, a flat oblong stop, L, Figs. 107 and 108, cast on one end of the templet block, is suitable. When bending a rigid bar, it is very difficult to get the extreme ends sufficiently curved. In this case the stop holds the end perfectly fast, and the curvature can be commenced from the very end. To prevent that end from rising during the process of bending, the clip, M (shown in detail at Fig. 110), is made to bear upon it. This is a piece of stout wrought iron pierced with a hole for the cottared pin, N, screwed into the bending templet. The long leg of the clip rests upon the face of the bending block; the short leg is pressed upon the bar to be bent by the cottar; the bar is thus pinched at one end.

The opposite end, if heavy, is supported by one of those appliances illustrated and described in Chapter I. A man, or two or three men if need be, stands at that end, and by main force pulls the bar round the curved templet, the supporting rest being moved along with the bar. The tendency of the bar to crumple up when the bending is taking place, is corrected by sledge hammer blows. Also to prevent the bar from becoming unequally curved, pins are inserted at intervals in holes cast in the plate, and iron wedges, O (Figs. 107 and 108), are driven between these pins and the bar.

Much force is required to pull round the roller, D, against the edge of the iron. To avoid having a long lever which might be in the way, a bar, P, is often slipped over the end of the radius bar, C, and removed when not in actual use. The mechanism of the roller, D, is shown in detail in Fig. 109. Along the bar slides a block, Q, which may be fixed at any radius with the wedge, R. A stout bolt, S, is screwed

into or forged on this block, and the roller, D, slips over it, and is held up by the nut underneath.

A heat cannot be taken over a great length in an ordinary forge fire. Therefore, after a short length, say from twelve to fifteen inches, of a bar is bent, it has to be released from the templet and put back into the fire to get the next section hot; and so on, until the entire ring is complete. Each time it is put back on the block, the portion already curved is secured with wedges. Sometimes also clips like M (Fig. 110) are cottared down over the bar to prevent it from rising.

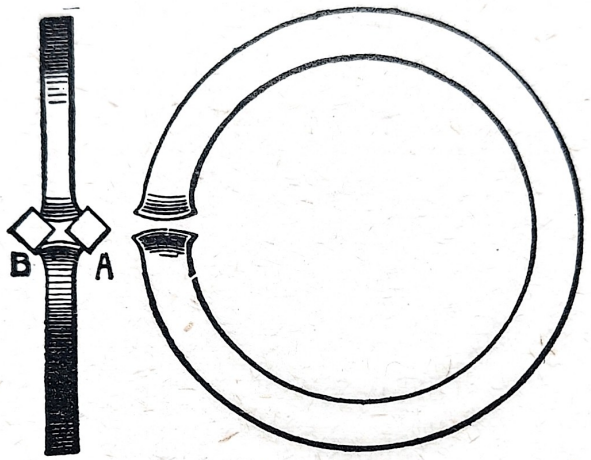

Fig. 112.—Method of Welding Ring.

When the circle is completed the ends have to be welded. The ends of the ring are upset before being brought together, and are spread in all directions. These upset edges are not welded together, but are united by "stick in" pieces. Into the V-like space formed on one side by the abutting ends, a square bar of iron, A (Fig. 112), is laid, and all being brought to the welding heat, a few blows of the hammer serve to unite the bar and the ends of the ring. Any length of bar that happens to be handy is taken, and it is not at first cut off to the length required. One end only is brought to a welding heat, the opposite cold end serving as a porter. After the welding is completed, the end is cut off with the hot set.

The ring is then turned over, and a similar "stick in" piece, B, is welded into the opposite V, precisely in the same fashion. The surfaces and edges are very rough and uneven; but the essential work is accomplished, and the rest is merely a matter of battering the faces with the flatter, and trimming the edges with the hot set and flatter. A heavy ring such as this cannot be manipulated easily until the smith's hands are relieved of its dead weight, so one of the appliances illustrated and described in Chapter I. is used.

If a ring, or segment of a ring, is wanted only a few inches larger than the ring, B (Figs. 107 and 108), for which the templet was made, the smith, to save the expense of a new block, will make a filling-up piece (Fig. 113) of square bar.

Fig. 113.—Iron Segment for Increasing Radial Capacity of Templet.

Fig. 114 shows a block of a type useful when a large number of complete rings of the same size are required. The principle of its construction is very similar to that rigged up on the levelling block (Figs. 107 and 108); but in this case a complete circular disc, A, instead of a segment, is used. A lever, B, is pivoted in the center of this disc by means of a cottar and pin, C, or a bolt. A roller, D, is pivoted on this lever. The ring is bent round the annular rebate, *a*, in the disc, and the roller, being pulled round with the lever, is pressed against the edge of the ring, which, confined between the roller, D, and the edge of a rebate on the disc, as shown by shading at *b*, cannot fail to become circular. The ring will have to be held down with clips, as in the previous example, for which purpose the holes cast in the

central part of the disc are utilized in the way already described.

A templet like this can also be used for rings slightly larger in diameter and of different widths, by placing rings around the central portion, *a*, of the rebate, and by altering the diameter of the roller, D. It is, of course, not necessary that the periphery of

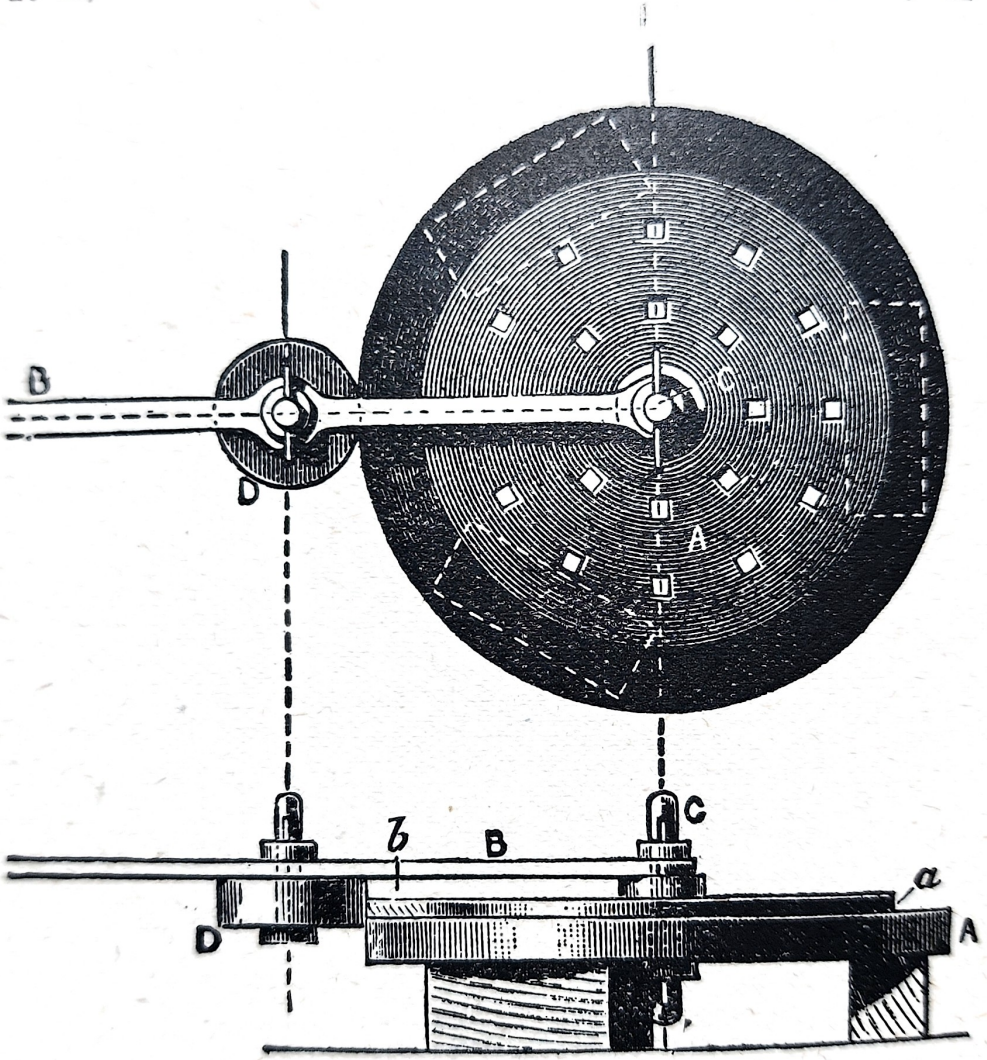

Fig. 114.—Circular Bending Block.

the roller should coincide with that of the disc. If the ring to be formed is larger than the outside of the disc, then the roller will be correspondingly smaller. If the ring is smaller than the disc, then the bottom of the roller will touch on the bottom of the rebated portion.

Slide-valve spindles of the bridle form are made in

two or three ways. The bridle is sometimes circular, sometimes rectangular in shape, but the principle of its formation is the same. In the circular form the eye may be bent round and welded as a distinct ring, and the stem then welded to the eye; by another method a portion only of the eye may be formed, and welded to another portion already made in one with a portion of the stem; by a third method the eye may be turned round and welded from the bar which forms the stem.

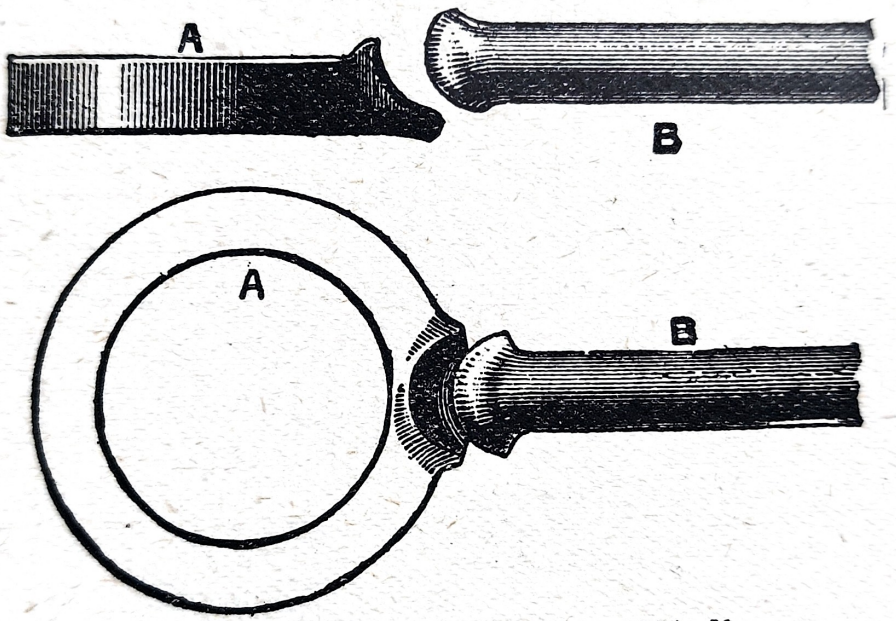

Fig. 115.—Welding Bridle to Spindle.

Fig. 115 illustrates the first method. Here A is the ring which has been upset, and scarfed, bent round on the anvil beak, welded and fullered to receive the upset and fullered stem B, placed in position for welding. The bar-iron from which the bridle, A, is made, is somewhat larger than the finished section—say ⅛ in. each way—and the ring is first bent round to a diameter smaller than that of the finished ring. This allows some finishing work to be done upon the bridle with fullers and flatter, which will have the effect of reducing the area and increasing the diameter. In this way the diameter of the ring may be increased to any reasonable extent, but it could not be reduced.

The ring is slipped over the anvil beak and its truth corrected with the hammer, or over a sugar-loaf-shaped casting (Fig. 114), flatters, fullers, and swages being employed for finally finishing the various flat and curved surfaces.

The bending of large bridles is best done in the manner shown in Fig. 116, and the same method is

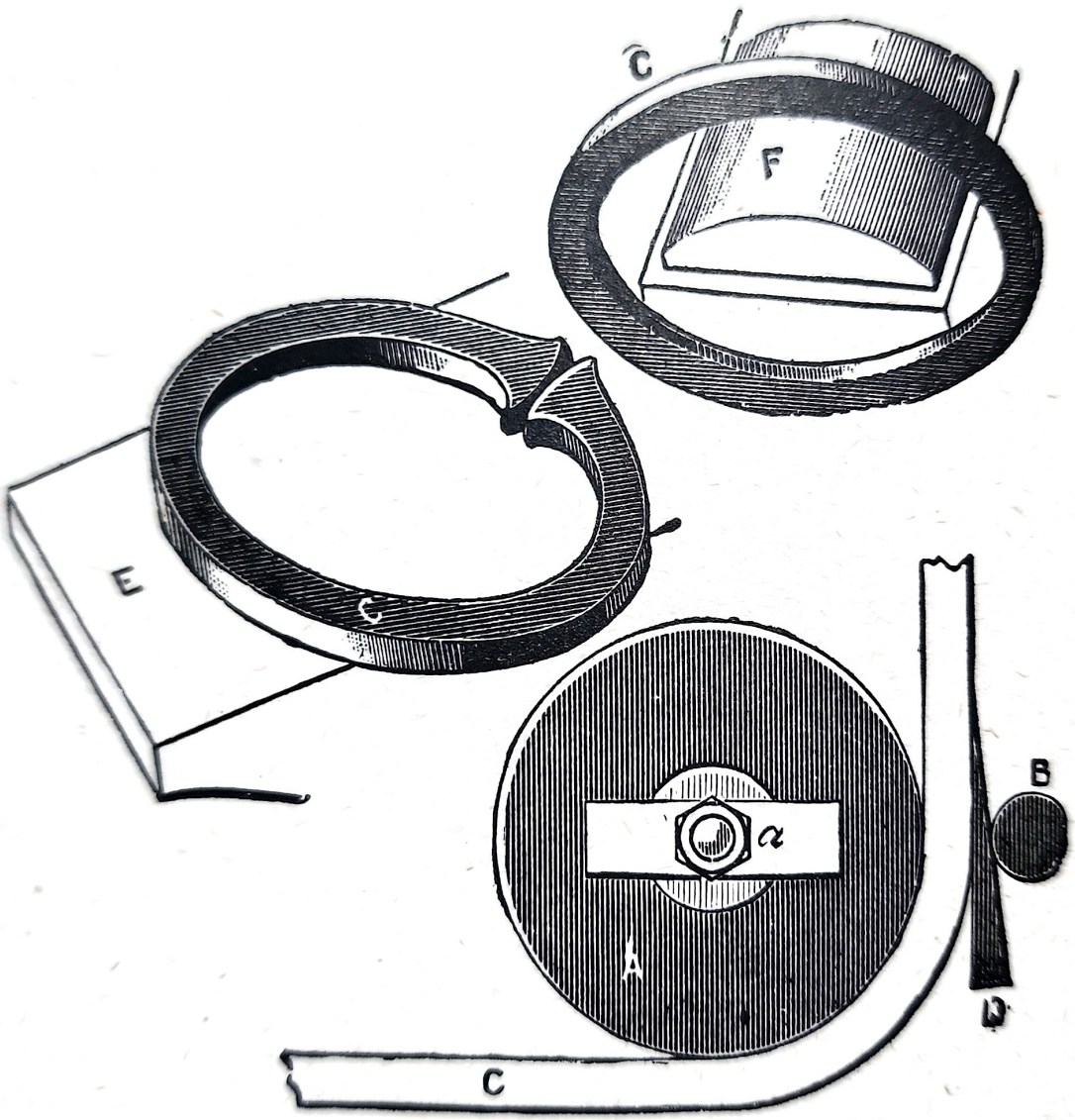

Fig. 116.—Method of Making Rings.

applicable to bending large rings in general. A cast-iron disc, A, of suitable size, and having a central hole, is bolted down on the face of a swage-block, the bolt *a* passing through one of the holes in the

block. At a suitable distance a stop or pin, B, is inserted in another of the holes. The bar, C, to be bent is heated and placed between the disc A and the stop B, and is held securely with an iron wedge, D; the free end is pulled round by hand if of sufficient length, or with tongs if short, and struck with the hammer the while to cause close bedding of the iron to the disc. When the ends of the intended ring overlap by an inch or two, it is removed, and the ends are scarfed and upset with the hammer or fullering tool, then welded upon the flat face of the anvil, E (Fig. 116), and finished upon a curved bolster, F, laid upon the anvil face, or provided with a shank to fit into the square hole in the anvil.

An alternative method (Fig. 117) of making the

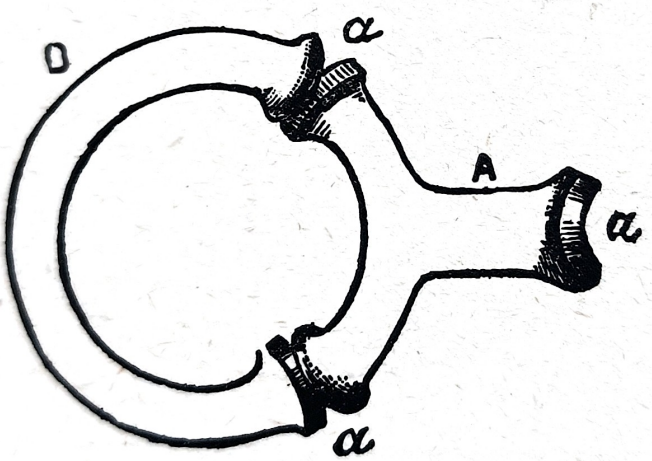

Fig. 117.—Method of Forming Bridle.

valve rod bridle is to take a rod of larger section than the valve rod, and fork one end by punching a hole and then driving in the hot set, first from one face, then from the opposite face, until the nicks meet in the center of the bar. Open out the divided ends into a curved form, and reduce slightly, so as to approximate to the finished dimensions, leaving the ends *a* (Fig. 117) of the original dimensions, and fullering them diagonally for scarfing (see A), which shows the T-piece finished for welding. The iron, B, that is to form the remainder of the ring,

will be curved, and fullered, and scarfed at the ends to match the T-piece, A.

At this stage the ring will be less than the finished

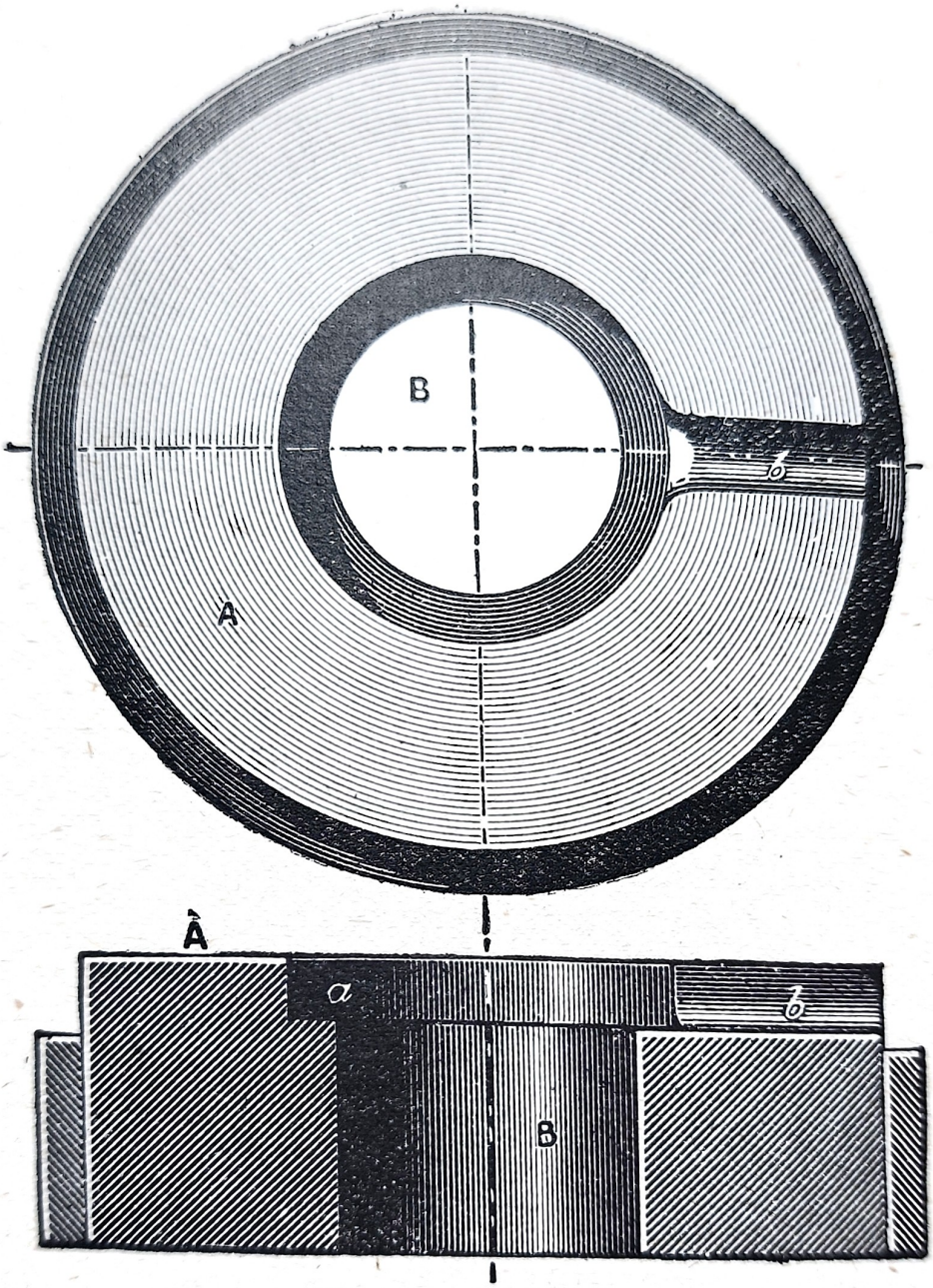

Fig. 118.—Die Block.

diameter—say by about ½ inch, dependent on the bulk of the work—to allow for working and finishing subsequent to welding, which stretches the iron. The spindle will be welded with a scarfed joint on to the

free end *a*, or if the spindle is short it may be drawn down from the T-piece itself.

Where many bridles are made alike for standard engines, a die block is employed for final finishing. Its shape is shown at Fig. 118. A is of cast iron, cored or bored out at *a* for the bridle, and cored out at *b* for the stem to lie in; B is a central steel plug or pin, the size of the hole in the bridle. The bridle is hammered into the die with a couple of blows of the steam hammer, next the die is turned upside down on a suitable bolster, and the pin B and the forging struck out at a blow. Then the pin is released from the forging, and the bridle is finished, except for cutting off with a set the fins around the top edges.

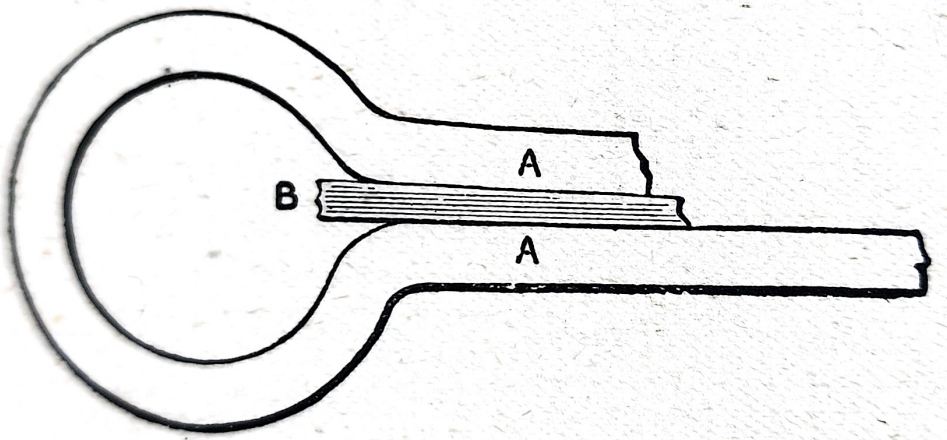

Fig. 119.—Method of Forming Bridle.

Fig. 119 shows the third method, in which the bar is bent round and welded at A. To preserve the continuity of the circle, a glut or wedge-piece, B, is inserted in the weld. Without this, by this method it would be difficult or impossible to form a perfect internal curve. The finishing of the bridle by means of tools and of dies, differs in no respect from that of the previous example.

The mode of making a rectangular bridle, unless of small dimensions, would be that shown in Fig. 120. Two T-pieces, A, A, are formed by division simi-

larly to the T-piece A in Fig. 117, and the remainder of the rectangle is formed of the two pieces, B, B, bent round and scarfed to meet the scarfed ends of the T-pieces. The rods may be drawn down from the ends of A, A, or welded on.

When a smith wants bending blocks of the kind mentioned in this chapter, it is as well to know that

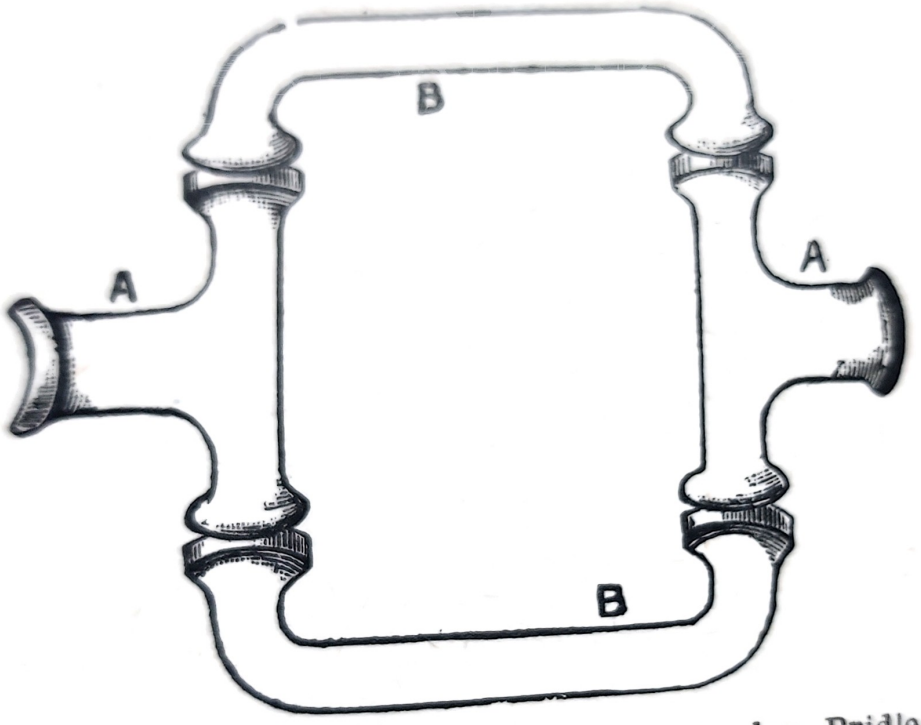

Fig. 120.—Method of Forming Rectangular Bridle.

complete wooden patterns are seldom made for them. A pattern segment of the block given to the iron-moulder, with a sketch or drawing of the complete block, with suitable instructions, is all that is required. The moulder will place any number of plain cores in the mould for the pin-holes.

CHAPTER VII.

MISCELLANEOUS EXAMPLES OF FORGED WORK.

The subjects now to be treated will embrace some of the common types of forgings, such as rods, levers, and bolts, made and used in the construction of machinery. Rods and links with bosses, like Fig. 121,

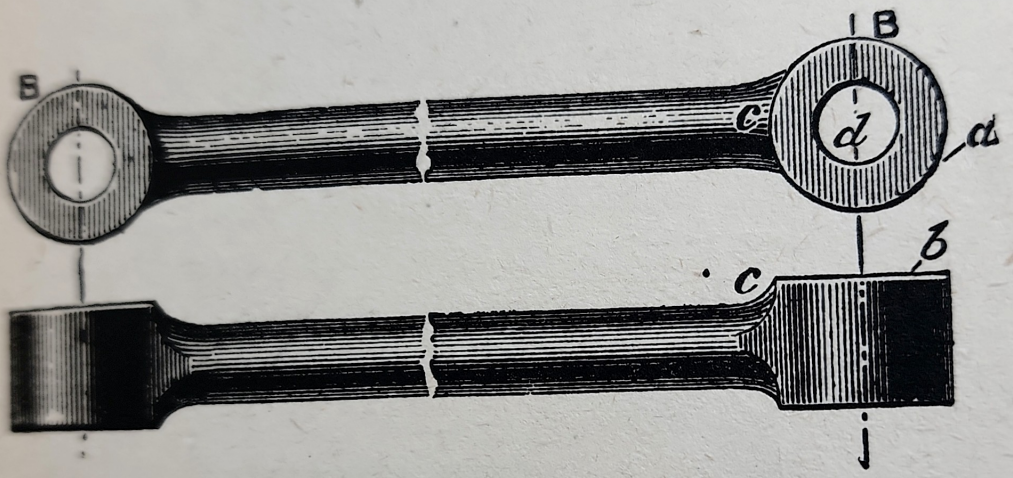

Fig. 121.—Rod or Link with Bosses.

are used extensively in various forms and proportions. At first sight, upsetting would appear to be the most ready method of making such rods. It seems simple to take a rod or bar, as the case may be, the size of the intermediate portion A and to dump up the ends to make the bosses B. But upsetting tends to open or spread the grain and to impair its continuity, and the operation would require several heats, and occupy much time, unless the bosses were very small.

There are three types at least:—(1) When the bosses are small relatively to their rods, and the rods are only a few inches long, as in some machinery links and levers, it is practicable, though not de-